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BULLETIN
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American Association *of* Petroleum Geologists

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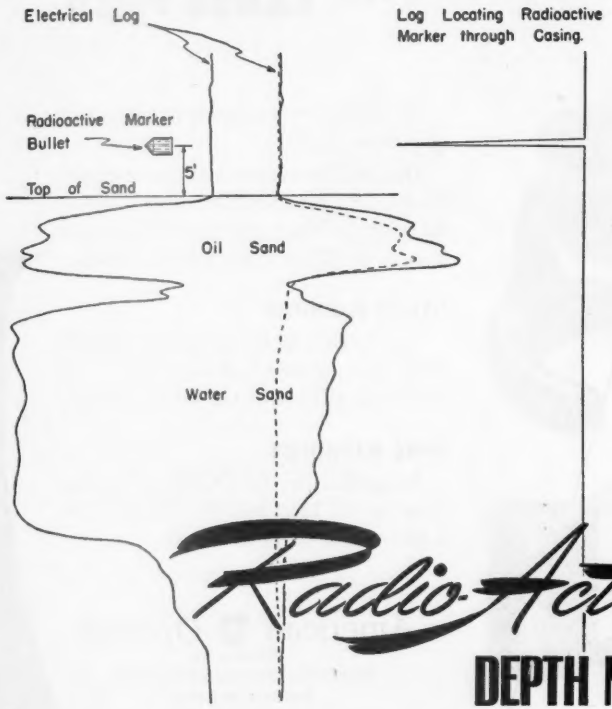

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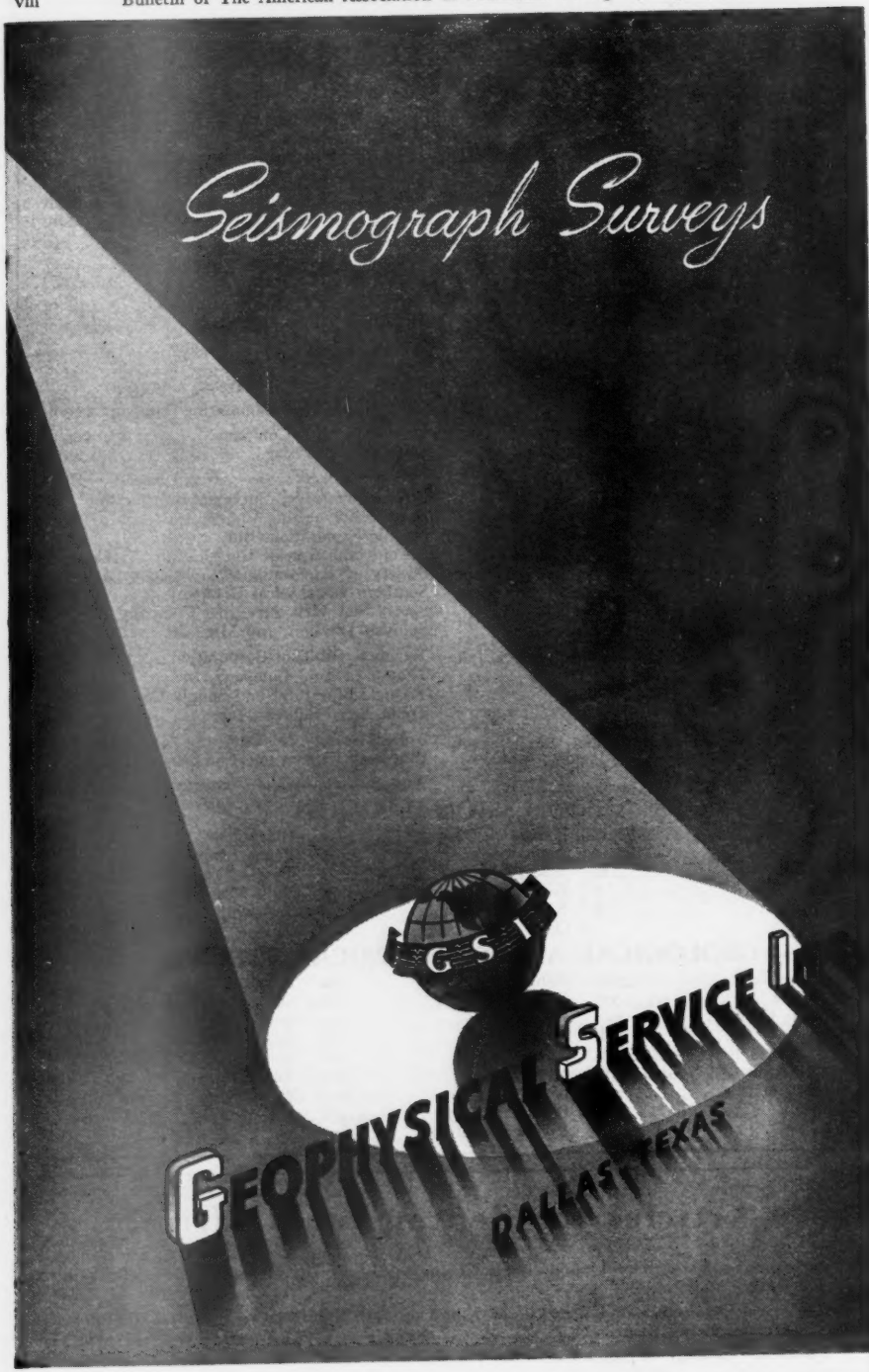
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AUGUST, 1946

SILURO-DEVONIAN STRATA IN CENTRAL KANSAS[1]

HALL TAYLOR[2]
Lyons, Kansas

ABSTRACT

The Siluro-Devonian Misener sandstone and underlying Hunton limestone are extensive in the subsurface section of central Kansas. They are only approximately equivalent in age to similarly named formations in the Oklahoma surface section.

The Misener is a shale and limestone-bearing sand which varies in thickness, and is missing in places. Its impure lithology, irregular distribution, and direct superposition upon both Ordovician and Siluro-Devonian rocks indicate formation during widespread pre-Mississippian erosion intervals.

In north-central Kansas the Hunton is primarily a dolomitic limestone. In a southwesterly direction it thins from several hundred feet to zero. Correlations based on chert lithologies indicate that lower Hunton beds disappear toward the southwest because of overlap in that direction, middle Hunton strata are the most extensive, and upper Hunton beds thin and disappear toward the southwest because of erosion, coupled with offlap toward the northeast. Most of the beds are regarded as Silurian, with Devonian present only in the northeastern part of the area, but fossil evidence is scant, and lithologic breaks are obscure.

Hunton limestones in south-central Kansas are normally less than 60 feet thick, and are not directly connected with those at the north. They cover a larger area than previously mapped, and extend into the region east of the buried Nemaha granite ridge. Inconclusive evidence indicates they are Silurian in age.

INTRODUCTION

Scope of paper.—The Siluro-Devonian Hunton limestone and overlying Misener sandstone occur in the subsurface section over much of central Kansas.

[1] Manuscript received, August 17, 1945.

[2] This paper is part of a dissertation submitted to the Department of Geology, Columbia University, New York City, in partial fulfillment of requirements for the Doctor of Philosophy degree. The research was done during portions of the summers of 1937, 1938, 1939, and continuously from the summer of 1940 to the fall of 1941. During the latter period it was supported by a William Bayard Cutting Traveling Fellowship from Columbia University. Professor Marshall Kay of Columbia University directed the study and helped prepare the manuscript for publication while the writer was in military service overseas. Professors R. C. Moore and K. K. Landes, respectively director and assistant director of the Kansas Geological Survey, provided equipment, well logs and samples. Among those offering helpful suggestions were Robert Carmody and Anthony Folger of the Gulf Oil Corporation, Edward A. Koester of Darby and Bothwell Inc., Wichita, Kansas, and Raymond Keroher, subsurface geologist of the Kansas Survey. Conclusions herein stated are the writer's own, and do not necessarily reflect views held by those who offered suggestions. To those here named, and to all others who helped in the preparation of this paper the writer extends sincere thanks.

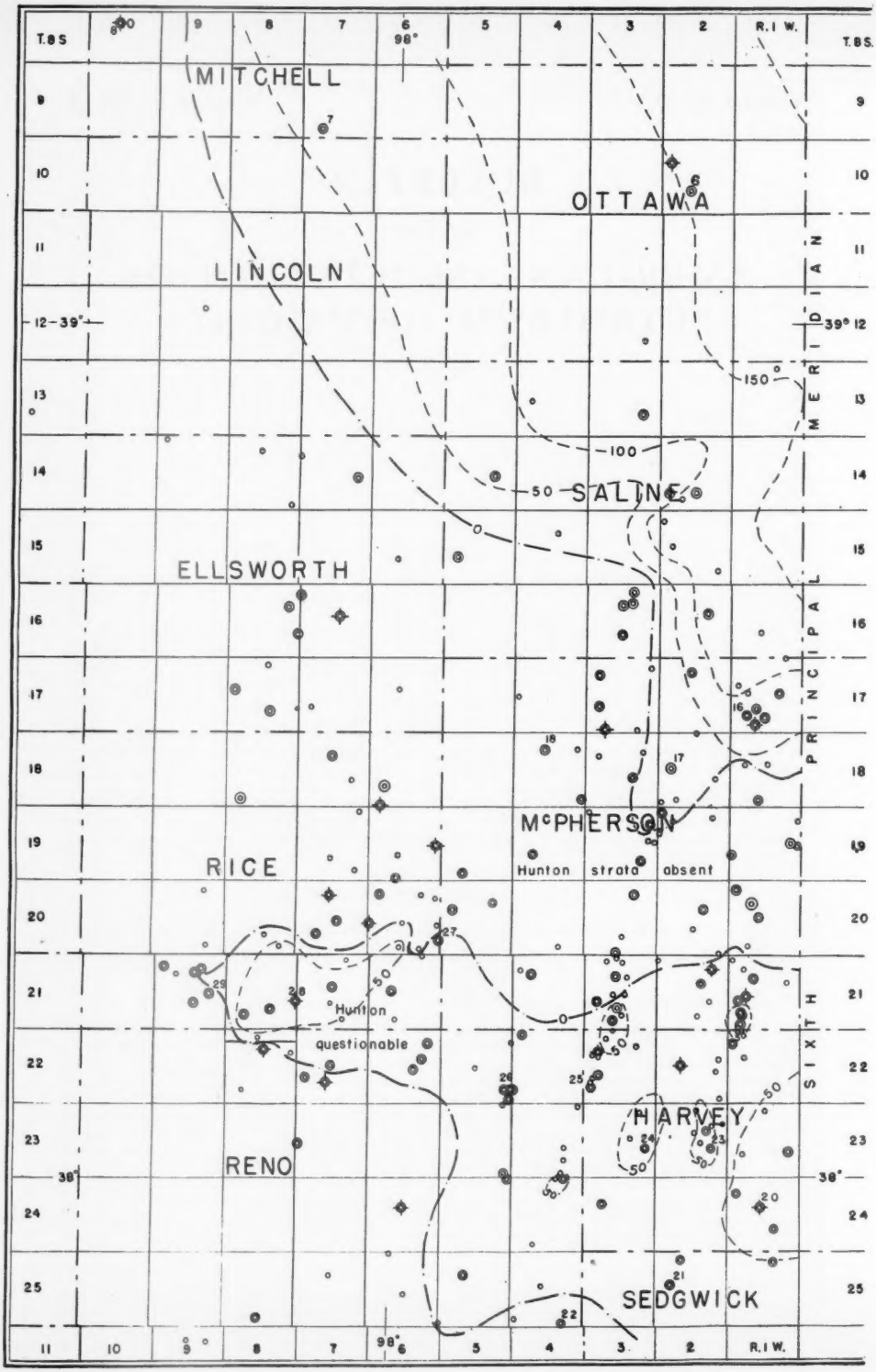
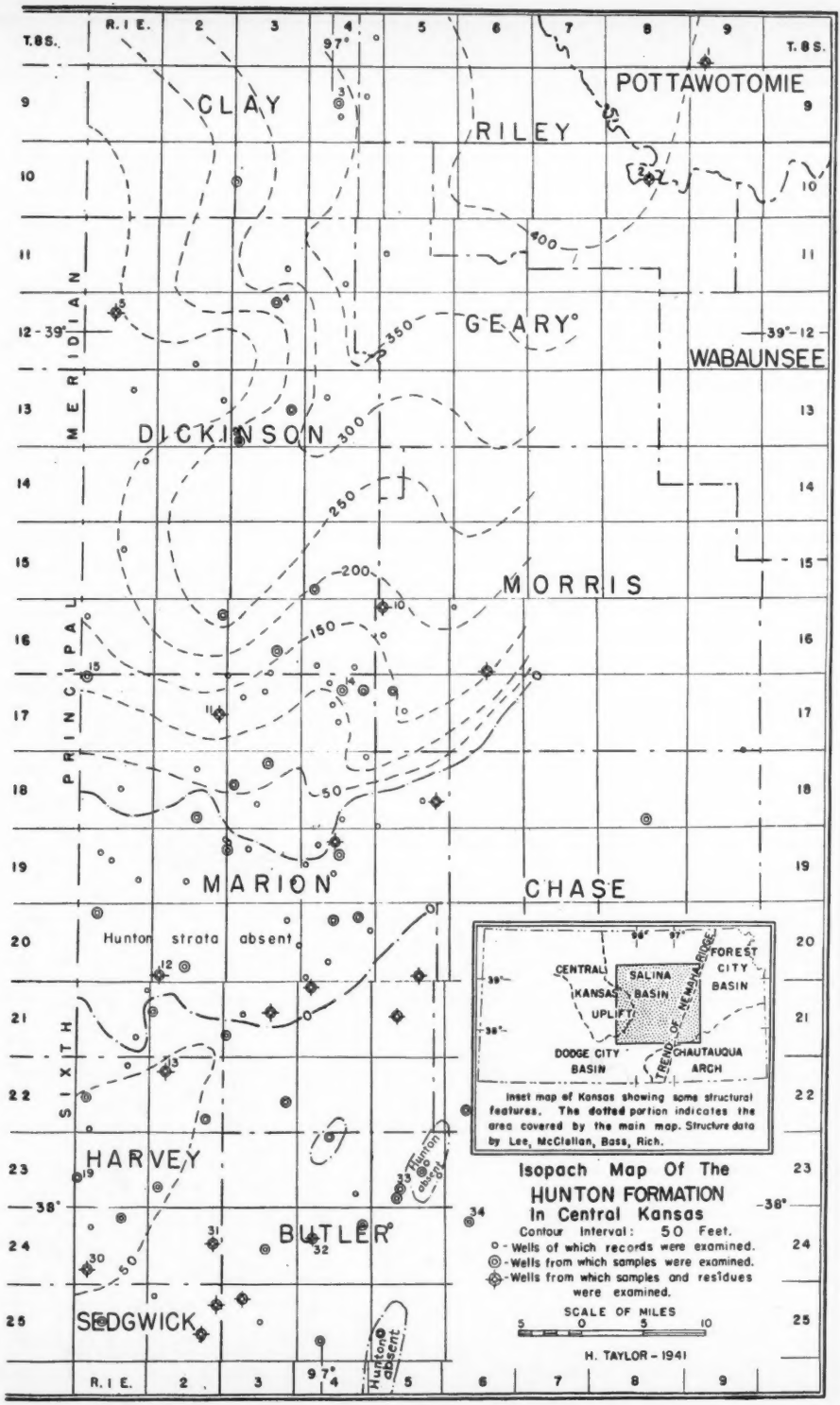


FIG. 1.—Isopach map of Hunton formation in central Kansas. Figures beside certain



wells refer to correspondingly numbered wells in cross sections *AA'* to *FF'*.

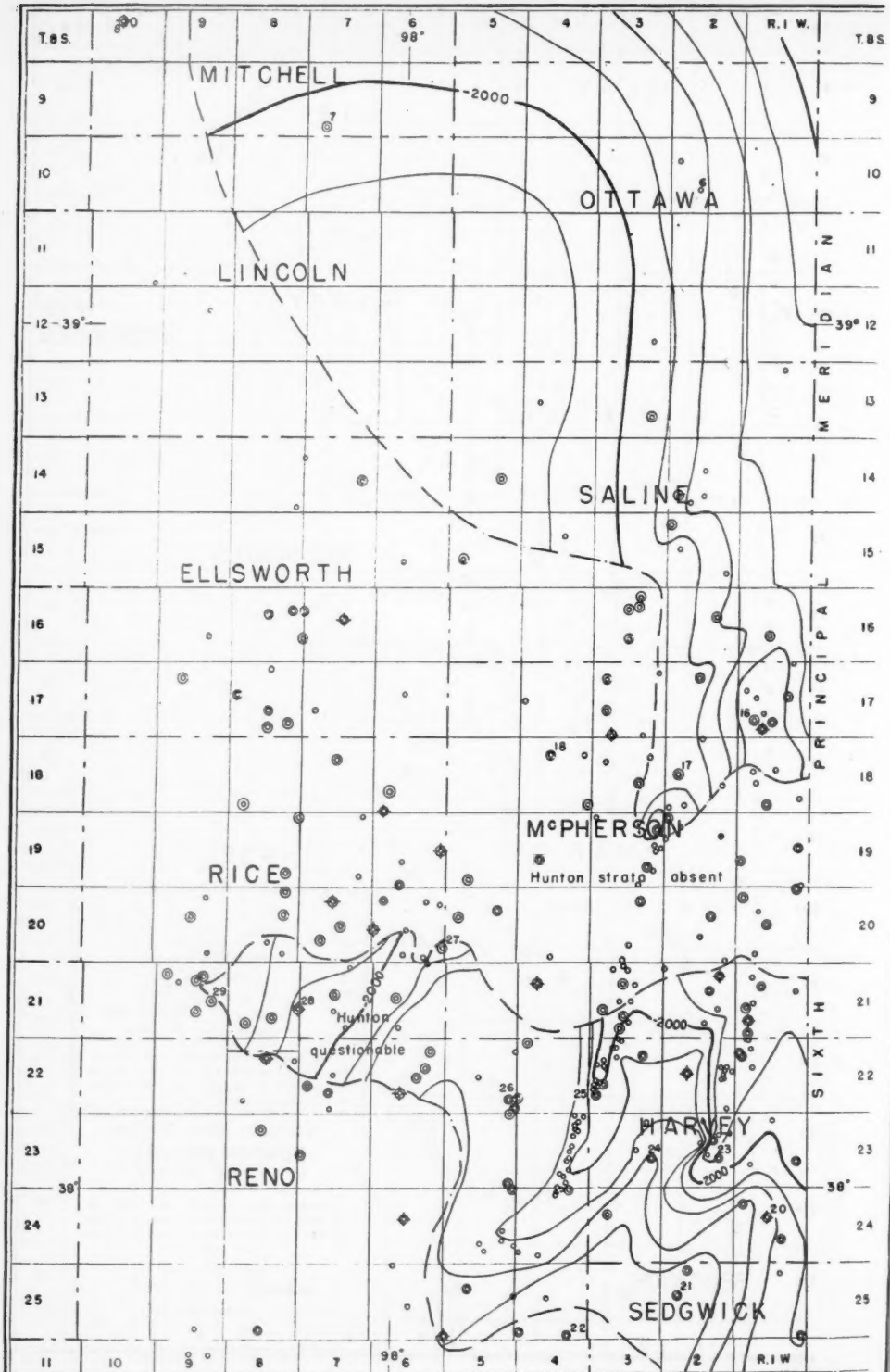
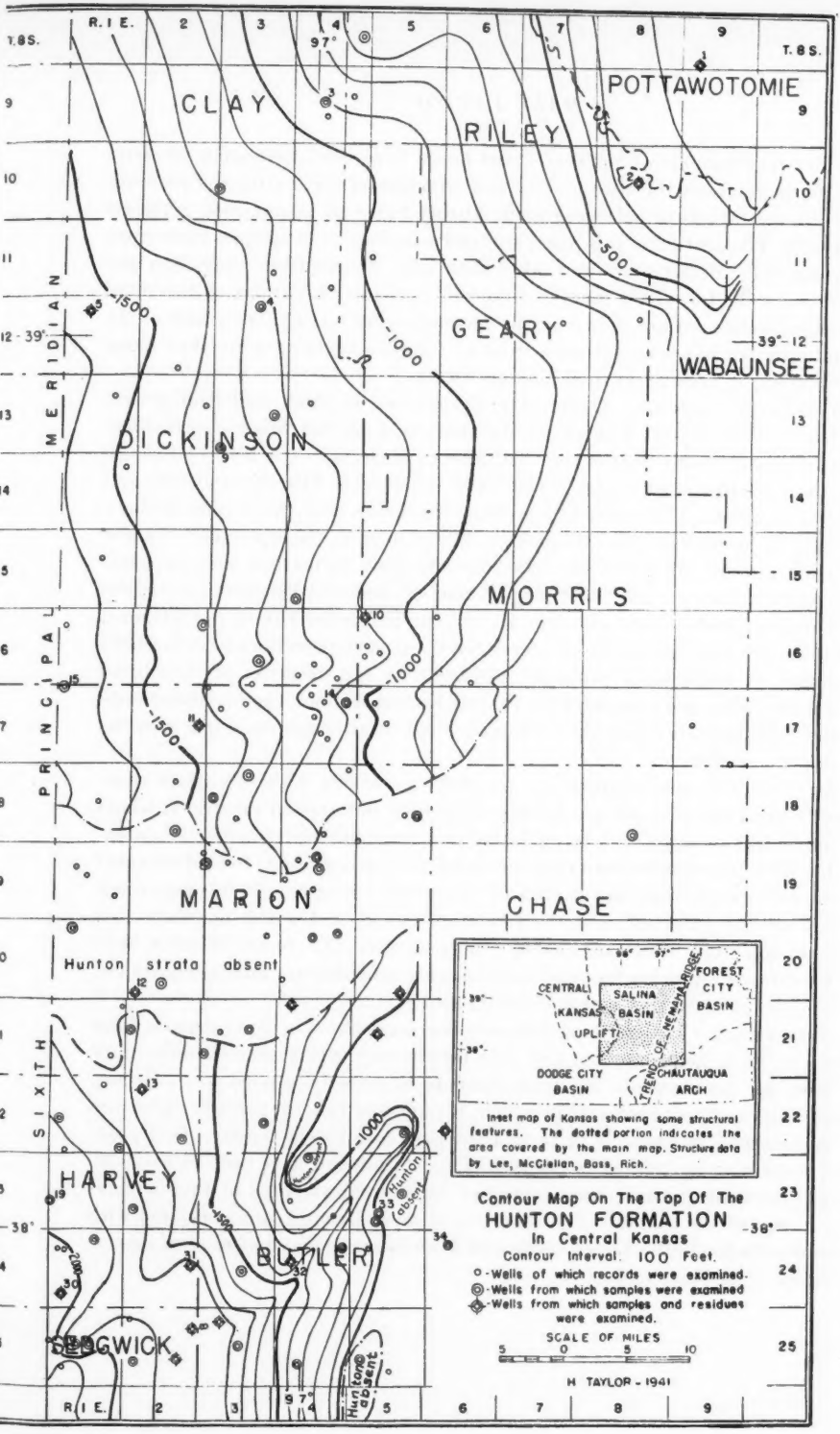


FIG. 2.—Contour map of top of Hunton formation in



central Kansas. Zero datum plane is mean sea-level.

In some areas they are oil reservoirs, and hence have special economic interest. This paper describes the stratigraphy and structure of the strata, and presents some interpretations of paleogeographic history based on information gathered from wells. Preparation of this paper entailed examination of samples from more than 300 wells; driller's logs and other data were utilized from more than 400 additional wells for which samples were not available. Locations of the more important wells used are shown on the accompanying maps (Figs. 1 and 2). In all, information has been gathered from 17 counties covering more than 9,000 square miles, an area larger than Massachusetts.

Stratigraphic sequence.—Quaternary, Cretaceous, Permian, and Pennsylvanian strata cover central Kansas. In the subsurface section Mississippian limestones disconformably overlie the Chattanooga shale, which is lower Mississippian or upper Devonian in age. Beneath this shale lie the Misener sandstone and Hunton limestone, both deposited in Siluro-Devonian time. Next come Ordovician strata, consisting of the Maquoketa-Sylvan shale at the top, under which in descending order are the Viola limestone, Simpson formation, and Arbuckle limestone or "siliceous lime" of drillers. Names of these mid-Paleozoic formations are borrowed from surface outcrops several hundred miles distant in Oklahoma and Iowa, but exact stratigraphic correlations with surface sections have not been published. A basal sand, probably Cambrian in age, rests on pre-Cambrian crystalline rocks, and completes the central Kansas section. The maximum sedimentary thickness is measured in thousands of feet although no single area has a complete section.

Stratigraphic nomenclature is a problem in working with subsurface rocks whose correlation with surface zones has not been determined exactly. It would be convenient to name each recognizable rock unit, but such practice is not desirable since it results in more than one name for the same unit, to be discovered when surface and subsurface studies are joined and compared. In this paper new names are not proposed; and the formation names of Hunton limestone and Misener sandstone, which are used by geologists working in central Kansas, have been retained despite the fact that such beds are probably not exactly equivalent to similarly named formations at the outcrops.

Terminology.—In describing dolomite-bearing rocks this paper departs from Mid-Continent field practice, and uses terminology which permits uniformity in lithologic descriptions. The term dolomite is properly applied to a calcium-magnesium carbonate mineral in which, if pure, the ratio of calcium carbonate to magnesium carbonate is 54.35 to 45.65 per cent. Yet in common field practice, rocks with as little as 50 per cent of such a mineral have been called dolomite, principally because they contained substantial amounts of that mineral and displayed the characteristic rhombs and crystalline texture associated with dolomitic rocks. In this paper *calcite* and *dolomite* are reserved as ***mineral*** names; *limestone* is used as a ***rock*** name.

There are many layers within the Siluro-Devonian beds of central Kansas which are largely dolomite, but some samples contain calcite. To call such rocks dolomite is not entirely accurate; they are limestones in which dolomite is preponderant, and are more accurately described as *dolomitic limestones*. If calcite predominates they are *calcitic limestones*.[3] If still more accurate descriptions are given, the percentages of the mineral constituents are listed.

SUBSURFACE STRUCTURES IN CENTRAL KANSAS

Introduction.—Two features, now buried, form the cornerstones of central Kansas subsurface structural geology (inset, Fig. 1). One, the Nemaha granite ridge, lies along the eastern edge of the area described in this paper; the other, the Central Kansas uplift, forms its western boundary. Between these two areas lies the Salina basin which itself contains minor folds.

Nemaha granite ridge.—The Nemaha granite ridge or arch trends somewhat east of north across east-central Kansas. It is flanked by upturned Mississippian limestones but covered by lower Pennsylvanian Bronson beds, indicating that the time of greatest uplift was early in the Pennsylvanian.

Central Kansas uplift.—The Central Kansas uplift, although now buried, was in middle Paleozoic time a relatively positive area. Koester[4] reviewed the structural and stratigraphic development, and concluded that its geologic history is similar to that of the Ozark dome of Missouri. Pre-Pennsylvanian strata are absent from much of the central area of the uplift, having disappeared on the flanks, and Pennsylvanian beds are thinner on the crest than on the flanks.

Kellum[5] called the Central Kansas uplift one of several "buried platforms" in the Mid-Continent area. The uplift did not furnish coarse clastics to the Salina basin region during mid-Paleozoic time, and its land surface probably was comparatively close to sea-level rather than being rugged or mountainous. Thus the term *platform* is more accurate etymologically than *uplift*, but the latter word is retained in this paper because of its widespread usage among those working in the area.

[3] Differentiation of calcite and dolomite in a field sample may be made by use of cold dilute hydrochloric acid or of Lemberg's solution. A more satisfactory method, used for many years at Innsbruck, Austria, has been described by H. W. Fairbairn ("Introduction to Petrofabric Analysis," *mimeographed booklet*, Queen's University, Kingston, Canada, 1935, p. 31), and was used in this study. With water, wet the surface of the fragment to be tested. Next, dip it in a 2½ to 5 per cent solution of ferric chloride for about 3 seconds. Rinse thoroughly in water to remove all free ferric chloride, and dip for another 3 seconds in ammonium sulphide saturated with hydrogen sulphide. Again rinse in water. Calcite turns black; dolomite remains unchanged. This test can be completed in about 10 seconds. Two refinements are possible. First, ammonium sulphide is normally unstable, but if kept in a stoppered bottle in which is a piece of pure copper the solution remains usable for long periods. Second, since only the sulphide ion is required in the reaction, potassium sulphide, which is relatively stable, may be substituted for ammonium sulphide if convenient.

[4] Edward A. Koester, "Geology of Central Kansas Uplift," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, No. 10 (October, 1935), pp. 1405–26.

[5] Lewis B. Kellum, "Geologic History of Northern Mexico and Its Bearing on Petroleum Exploration," *ibid.*, Vol. 28, No. 3 (March, 1944), p. 302.

Salina basin.—Barwick[6] defined the Salina basin as the syncline between the Nemaha ridge and Central Kansas uplift, and noted that on the south it was limited by a saddle in McPherson County between these two positive areas, but on the north its limits were unknown. In Republic County, Kansas, near the Nebraska line the Siluro-Devonian limestones in the basin are as extensive as farther south, being more than 200 feet thick. The basin extends into Nebraska, but because of limited drilling its northern limits are not accurately defined.

North Kansas basin.—Prior to Pennsylvanian time the Salina basin and most of northeastern Kansas were probably part of a single intermittently sinking area, named the North Kansas basin by Rich.[7] Rise of the Nemaha arch bisected the North Kansas basin and produced the Salina basin.

Minor structures.—Several small anticlines occur between the Central Kansas uplift and the Nemaha ridge. The most prominent is the Voshell anticline crossing central McPherson, western Harvey, and eastern Reno counties. The axis of this fold trends northeast and southwest and is the site of several oil fields. This fold, as well as others in central Kansas, was probably formed by compressive forces operating in the earth's crust between the Central Kansas uplift and the Ozark dome.

MISENER FORMATION IN CENTRAL KANSAS

Stratigraphy and structure.—In some wells an irregular impure limy or shaly sandstone, ordinarily not more than 10 feet thick, lies beneath the Chattanooga shale. Leatherock and Bass[8] report that in northern Oklahoma this sandstone is only a few inches thick, and is considered a basal member of the Chattanooga shale. It there overlies various formations some thought to be at least as old as Simpson, but in central Kansas it lies on Viola, Sylvan, and Hunton beds. In places it is an oil reservoir.

The sand normally is fine and angular, but contains small amounts of coarser grains, some of them frosted (Fig. 3). In many wells the sand grains are embedded in a dolomitic or shaly matrix, and in a few holes, clean closely spaced samples show thin sand layers within basal spore bearing gray Chattanooga shale, as in the Allison-Fitzwilliam Corporation's Fulton test No. 1 (Sec. 24, T. 19 S., R. 6 W.) between 3,780 and 3,790 feet.

Kansas oil geologists have called this the "Misener sand" because of its stratigraphic position beneath the Chattanooga shale. Some have correlated it with the lower Mississippian Sylamore sandstone, but it is not everywhere the same age. Its thinness, fine-grained texture, irregular distribution, and super-

[6] John S. Barwick, "The Salina Basin of North-Central Kansas," *ibid.*, Vol. 12, No. 2 (February, 1928), pp. 177–99.

[7] John L. Rich, "Distribution of Oil Pools in Kansas in Relation to Pre-Mississippian Structure and Areal Geology," *ibid.*, Vol. 17, No. 7 (July, 1933), p. 796.

[8] Constance Leatherock and N. W. Bass, "Chattanooga Shale in Osage County, Oklahoma, and Adjacent Areas," *ibid.*, Vol. 20, No. 1 (January, 1936), p. 96.

position on various formations, above which is a black or gray shale, indicate a long pre-Chattanooga erosion interval during which near-by land was near base-level.

HUNTON STRATA IN NORTH-CENTRAL KANSAS

GENERAL SURVEY

Stratigraphy.—Crystalline dolomitic limestones containing three prominent chert bands comprise the thickest sections of the Hunton formation in the Salina basin in north-central Kansas (Fig. 4). The highest chert band, here

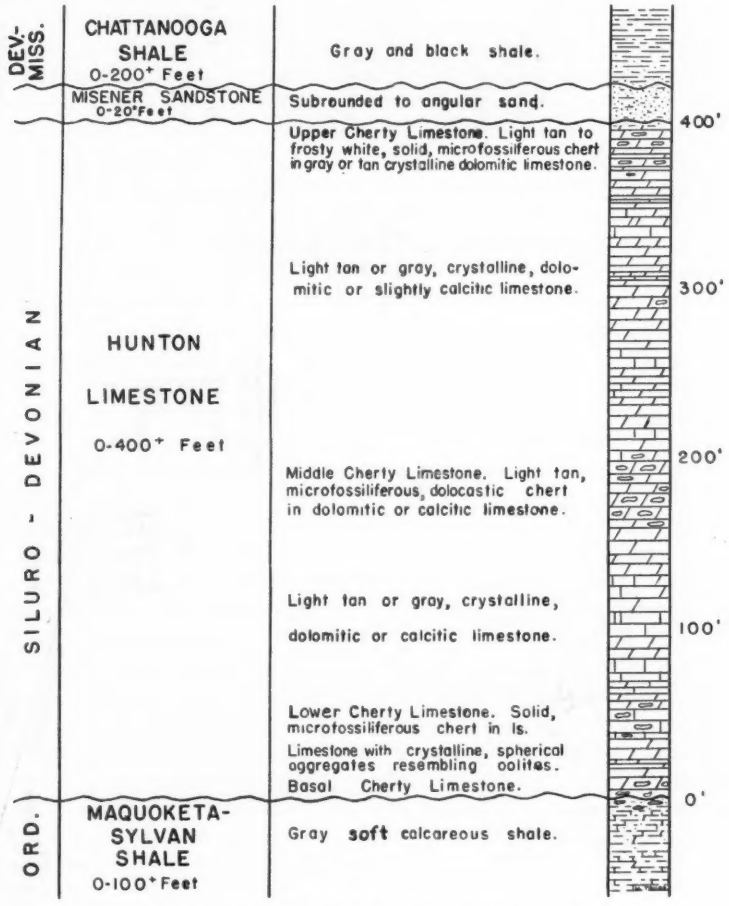

DEV.-MISS.
CHATTANOOGA SHALE
0-200+ Feet
Gray and black shale.
MISENER SANDSTONE
0-20 Feet
Subrounded to angular sand.
400'
Upper Cherty Limestone. Light tan to frosty white, solid, microfossiliferous chert in gray or tan crystalline dolomitic limestone.
Light tan or gray, crystalline, dolomitic or slightly calcitic limestone.
300'
SILURO - DEVONIAN
HUNTON LIMESTONE
0-400+ Feet
200'
Middle Cherty Limestone. Light tan, microfossiliferous, dolocastic chert in dolomitic or calcitic limestone.
Light tan or gray, crystalline, dolomitic or calcitic limestone.
100'
Lower Cherty Limestone. Solid, microfossiliferous chert in ls.
Limestone with crystalline, spherical aggregates resembling oolites.
Basal Cherty Limestone.
0'
ORD.
MAQUOKETA-SYLVAN SHALE
0-100+ Feet
Gray soft calcareous shale.

FIG. 4.—Generalized geologic column of Misener and Hunton formations in north-central Kansas.

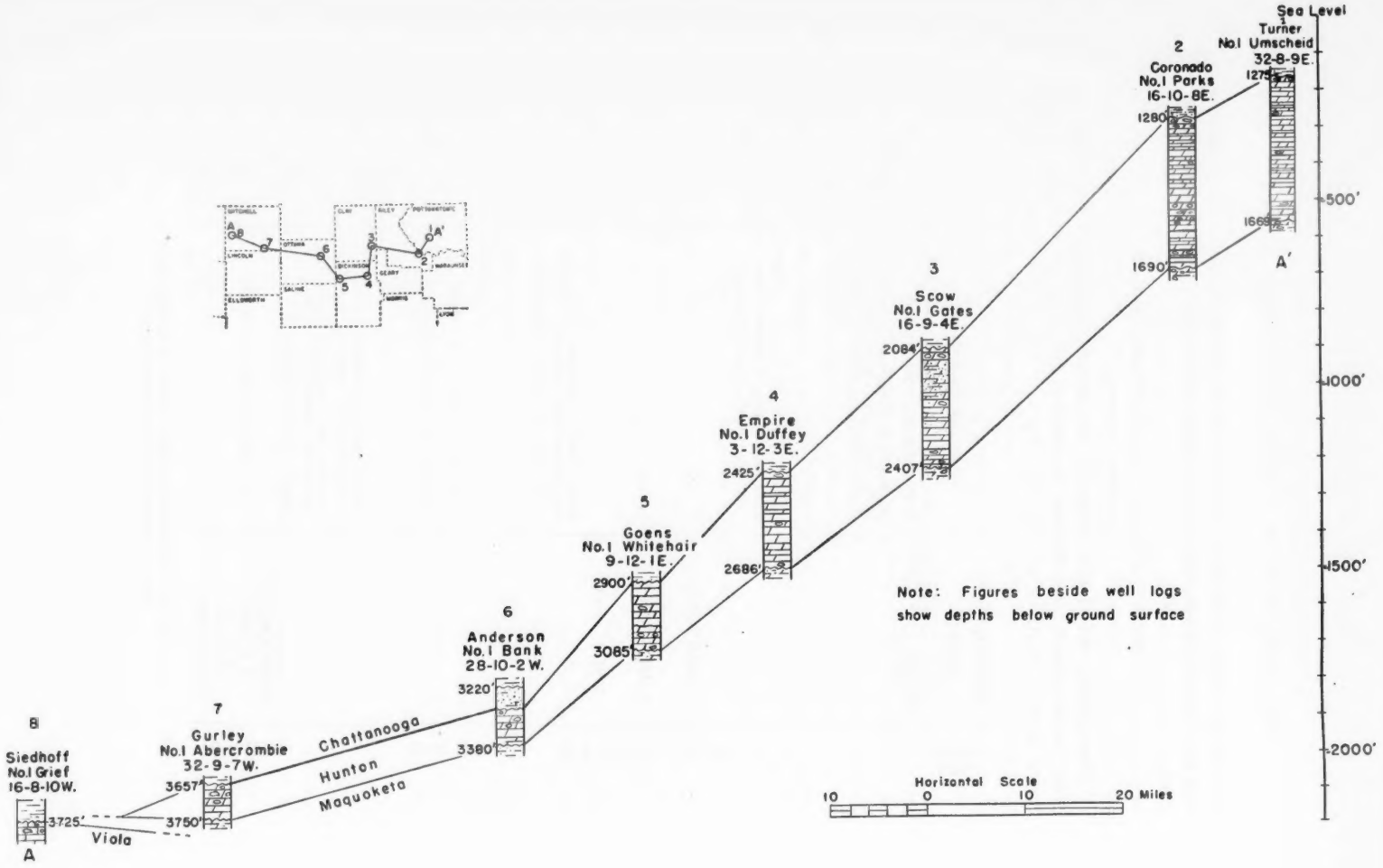


FIG. 10.—Geologic cross section of Hunton strata along line *AA'* in north-central Kansas (see inset index map).

called the upper cherty limestone zone, occurs near the top of the section, and carries chert which is microfossiliferous, light tan to frosty white, and normally non-dolocastic in residues (Fig. 5). The middle cherty limestone zone is similar except that fragments in residues from the northern and eastern parts of the basin are commonly dolocastic (Fig. 6). This member is the most widespread of the three chert zones, and in the southwestern part of the Salina basin is believed to be the only chert present. The lowest chert band, called the lower cherty limestone zone, occurs near the base of the section. Its chert is frosty white to light tan, microfossiliferous, and commonly non-dolocastic in residues (Fig. 7). The limestone between the upper and middle cherty zones is, for purposes of identification in this paper, called the upper limestone zone; between the middle and lower cherty zones is the middle limestone zone; and below the lower cherty zone is the lower limestone or crystalline oölite zone. Formal names are not appended to any rock divisions since exact correlations with surface outcrops are unknown.

Over most of the Salina basin the limestone is uniformly crystalline, dolomitic, and light tan to light gray (Fig. 8). Some beds, especially near the southern and western edges of the basin, contain crystalline calcitic limestone. Small amounts of light apple-green shale occur in samples of the dolomitic limestone above the middle cherty zone in the northeastern part of the Salina basin. Possibly such shale is confined to Devonian rocks. Some sandy zones are present, particularly in areas near the Nemaha arch and Central Kansas uplift.

The crystalline oölite or lower limestone zone occurs within 25 feet of the base of the Hunton, and is light tan crystalline dolomitic limestone. Fragments from some wells are partially rounded and form roughly spherical aggregates (Fig. 9). This rounding can not be ascribed to accidental churning action during drilling in a single well since similar rounded aggregates occur in samples from points as widely separated as eastern Clay County and northwestern Marion County about 60 miles distant. Lee[9] notes that oölitic beds occur near the base of Silurian rocks in Oklahoma, northeastern Kansas, and Missouri. It is believed this is a distinctive separate bed which may in the future be judged worthy of formation rank.

Structure.—The greatest thickness of Hunton strata in the Salina basin occurs in the northeastern part where there are about 400 feet of dolomitic limestone and chert. Beds thin toward the south and west, and disappear near the edge of the Central Kansas uplift (Fig. 1). Over most of the area the strata dip west and south (Fig. 2) although near the uplift they are approximately horizontal. Reversals of dip occur on the east sides of the Voshell, Saline, and other anticlines. As a result of post-Hunton movements very little basin structure is apparent in cross sections of Hunton strata (Figs. 10, 11, 12).

[9] Wallace Lee, "Stratigraphy and Structural Development of the Forest City Basin in Kansas," *Kansas Geol. Survey Bull. 51* (1943), pp. 44, 45, 49.

FIG. 10.—Geologic cross section of Hunton strata along line *A-A'* in north-central Kansas (see inset index map).

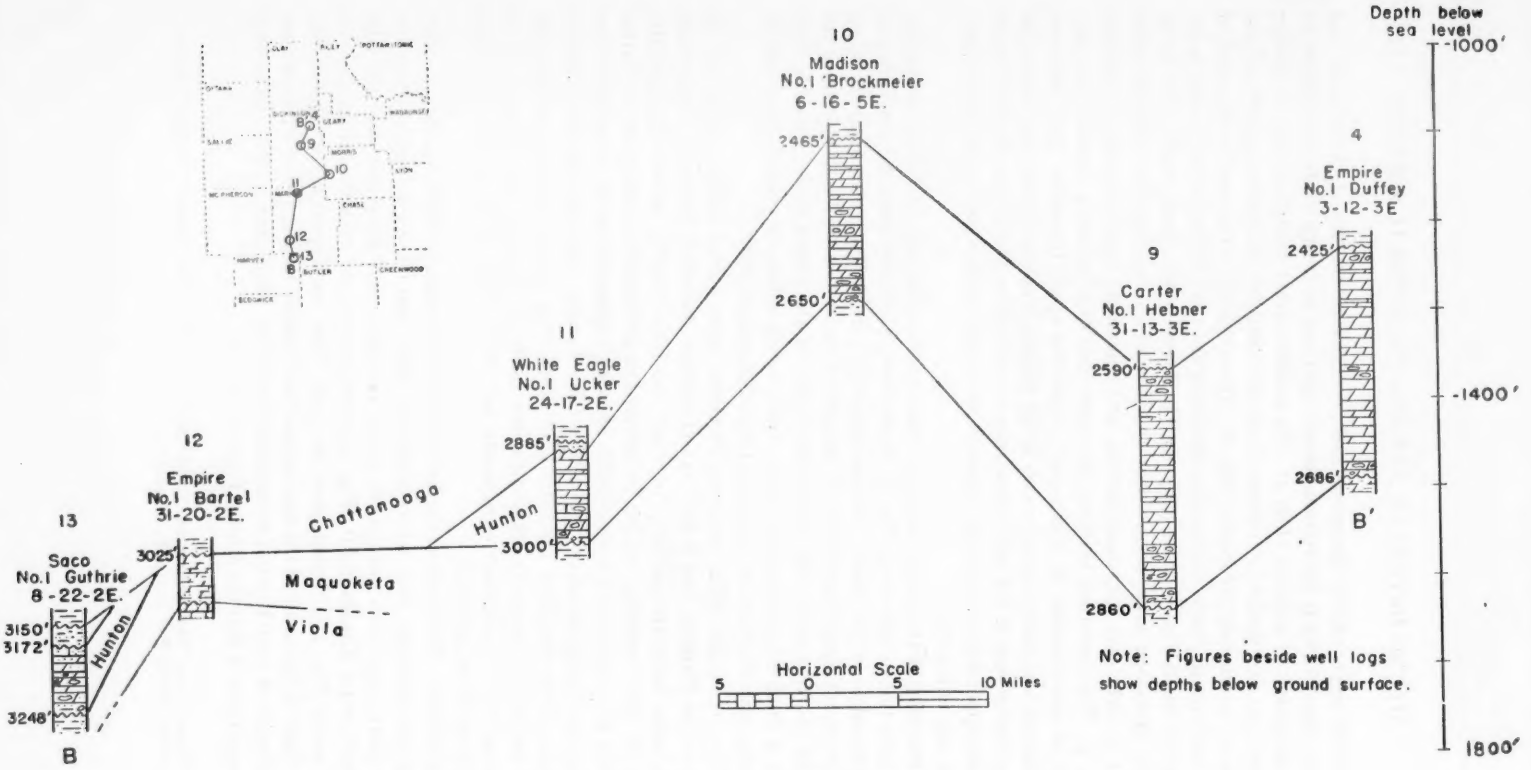


FIG. 11.—Geologic cross section of Hunton strata along line *BB'* (see inset index map) in north-central Kansas.

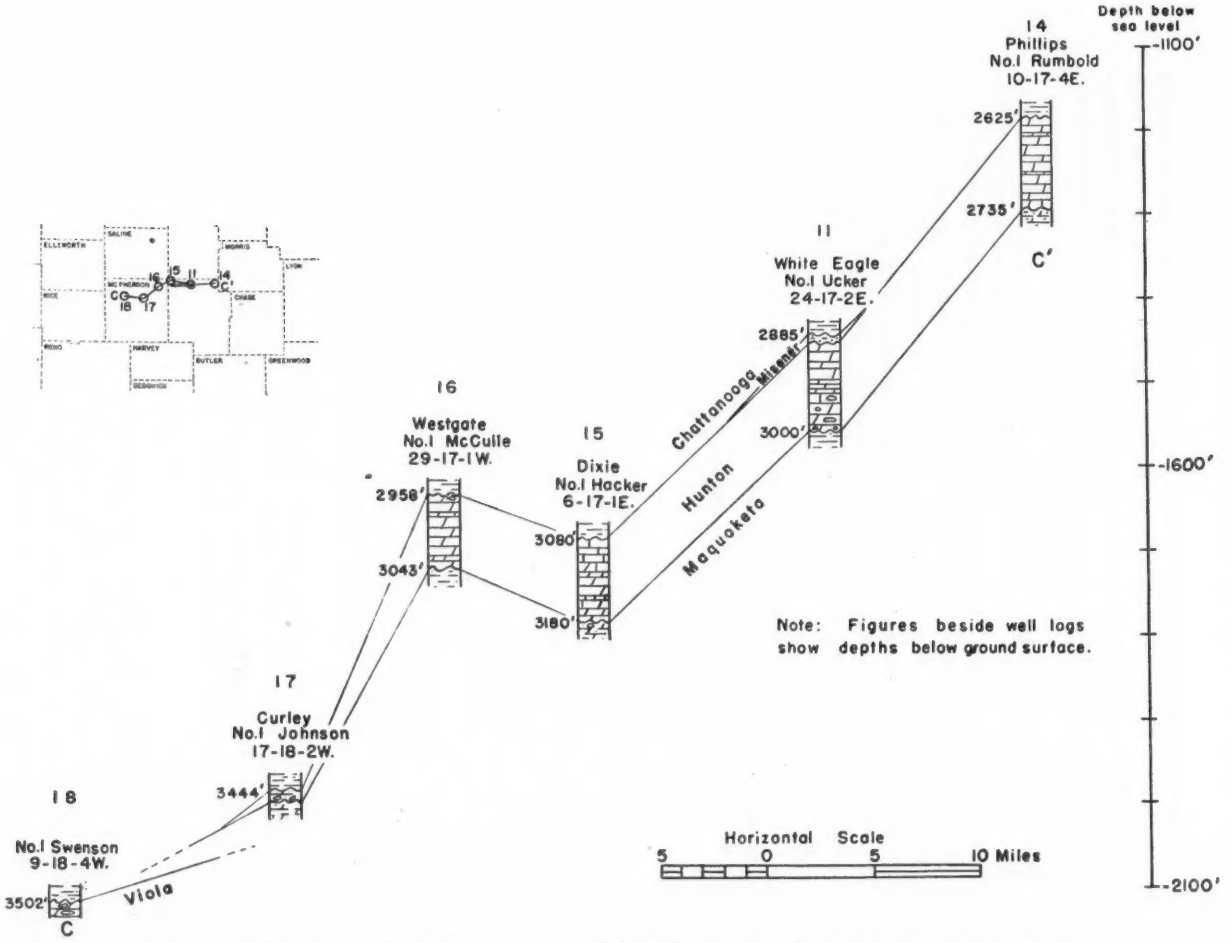


FIG. 12.—Geologic cross section of Hunton strata along line *CC'* (see inset index map) in north-central Kansas.

Paleogeography.—Prior to the late Paleozoic uplift of the Nemaha granite ridge the site of the Salina basin lay in the southwestern part of the larger North Kansas basin. Seas filling this area deposited Siluro-Devonian strata. The paleogeographic record of advances and withdrawals of mid-Paleozoic seas is not entirely clear. However, it is suggested that in lower Hunton time there was a gradual overlapping of the Salina basin by a sea from the northeast, with deposition of the crystalline oölite or lower limestone beds as far southwest as northwestern Marion County. The overlying lower cherty and middle limestone zones were deposited successively farther southwest, and the still higher middle cherty zone was laid down over the largest area of all. Deposition during this period probably was not continuous. Following the deposition of these beds there was a break in sedimentation, but the land remained close to sea-level, and little erosion took place. This break may be the line between Silurian and Devonian rocks.

Next, the upper limestone and upper cherty zones were deposited in the northeastern part of the Salina basin; but in the southwest, dune and shore sands are the only deposits of this period, which may belong in the Devonian. Erosion, coupled with formation of Misener sand deposits, followed the close of Hunton deposition.

In some wells sandy layers appear within the Hunton limestone. Such occurrences are more common in holes near the Nemaha arch and the Central Kansas uplift than in the center of the Salina basin. The uplift was probably a source of sands in Hunton time, but the Nemaha arch rose in the late Mississippian and early Pennsylvanian. Sands in Hunton strata of Riley County and near-by regions are believed derived from one or more positive areas, perhaps of limited areal extent, which were located near the site of the present Nemaha arch, but which were formed prior to the rise of that structure. Well data are insufficient to supply evidence on thinning of Hunton strata adjacent to such possible positive areas. However, thick Hunton sections encountered adjacent to the Nemaha arch indicate there was no general rise of that structure during Hunton deposition.

It should be emphasized that the hypotheses here proposed are based on examination of samples from a limited number of wells, and are intended only as one interpretation of observations. Undoubtedly they will require modification as further information becomes available.

POTTAWATOMIE AND RILEY COUNTIES

Stratigraphy.—The thickest Hunton section in central Kansas lies in Pottawatomie and Riley counties (Fig. 1). In western Pottawatomie County, J. A. Turner's Umscheid test No. 1 (NE. ¼, SW. ¼, Sec. 32, T. 8 S., R. 9 E.) penetrated 394 feet of Hunton beds, principally dolomitic limestones (well No. 1, cross section *AA'*, Fig. 10). In eastern Riley County samples from the Coronado Oil Company's Parks well No. 1 (SE. ¼, SE. ¼, Sec. 16, T. 10 S., R. 8 E.) show

410 feet of Hunton dolomitic limestone and chert intermixed with minor amounts of calcitic limestone and clear to frosted subrounded sand (well No. 2, cross section *AA'*, Fig. 10). Samples from the Parks well show the following zones.

LOG OF CORONADO OIL COMPANY'S PARKS NO. 1, SEC. 16, T. 10 S., R. 8 E.

Depth (Feet)	*Description of Zones*
1,260–1,280	EROSIONAL ZONE AT TOP OF HUNTON. Mixture of light gray and vari-colored shales, and angular to subrounded sand grains
–1,310	UPPER CHERTY ZONE (Fig. 5). Samples contain about 50 per cent light or medium brown, finely crystalline to dense, nearly pure dolomitic limestone; and 50 per cent microfossiliferous, light tan, gray or white chert, which is nondolocastic in residues. Some chert fragments are smooth, others are rough. One type has a surface which resembles hoar frost or compressed cotton
–1,480	UPPER LIMESTONE ZONE. Light tan or brown crystalline dolomitic limestone, with a few gray layers near base. Some samples below 1,350 feet contain 10 to 25 per cent calcitic limestone which closely resembles its dolomitic counterpart. A few fragments of light apple-green shale. Residues are scant, but contain some drusy quartz crystals, angular sand, and light gray shale (cave ?)
–1,540	MIDDLE CHERTY ZONE (Fig. 6). Samples contain 50 to 75 per cent light tan to medium brown finely crystalline dolomitic limestone; and 25 to 50 per cent light tan microfossiliferous rough- to smooth-surfaced chert, some of which appears as though covered with frost crystals or matted cotton fibers. In residues some chert pieces are smooth and solid, more are dolocastic, and a few are spongy
–1,635	MIDDLE LIMESTONE ZONE.[10] Light tan or gray crystalline dolomitic limestone. Residues show a few silicified fragments of crinoid stems and other fossils
–1,660	LOWER CHERTY ZONE (Fig. 7). Samples contain about 80 per cent light tan finely crystalline dolomitic limestone; and 20 per cent microfossiliferous chert which normally is non-dolocastic in residues, and ranges in texture and color from rough frosty white to smooth light tan. A few fragments show both sorts of chert in same piece. Silicified crinoid columnals present
–1,690	CRYSTALLINE OÖLITE OR LOWER LIMESTONE ZONE (Fig. 9). Light tan finely crystalline dolomitic limestone, some fragments of which are roughly spherical aggregates of crystals
–1,700	EROSIONAL ZONE AT BASE OF HUNTON. About 50 per cent light tan crystalline dolomitic limestone similar to overlying beds, and 50 per cent medium gray dirty-looking chert which in residues is abundantly dolocastic

Cherts within the three cherty zones are microfossiliferous and of secondary origin. They are mixed with varying amounts of sand grains and crystalline quartz, which may be the source material from which they are derived. Siliceous and arenaceous material is more abundant in the Parks than in the Umscheid well, suggesting that southwestern Riley County may in Hunton time have been nearer a protruding landmass furnishing sandy sediments than was west-central Pottawatomie County.

The Hunton age of the upper cherty zone in this area might be questioned. The chert resembles that found in some Mississippian rocks. Chattanooga shale is missing in the area; the pre-Pennsylvanian and post-Ordovician section is primarily limestone; fossils are unknown; and correlation by lithology may not be considered entirely certain. However, the middle cherty and upper limestone zones resemble known Hunton rocks on the southwest; and there is no indication of an unconformity between the upper cherty and upper limestone

[10] Wallace Lee, *op. cit.*, p. 56, places the base of the Devonian at about 1,540 feet in this well. This is approximately 60 feet lower than the horizon tentatively suggested in this paper.

zones. It is believed the entire limestone section is of Hunton age with Mississippian rocks missing from the area.

Definite evidence of an erosional break within the Hunton was not observed in these counties. Of possible significance is the presence of a few pieces of light apple-green shale above but not below the middle cherty zone. Also the upper limestone zone contains more calcite than do Hunton strata lower in the section. If, as previously proposed, the middle cherty zone marks the top of the Silurian, the green shale and relatively abundant calcite occur in Devonian beds.

Structure.—Hunton strata dip gently to the southwest (Fig. 10) into the Salina basin, and thin gradually in the same direction. Present structural trends are largely the result of late Paleozoic uplift of the Nemaha ridge. Sands within Hunton beds suggest that there may have been near-by exposed areas furnishing siliceous material to Hunton seas. Well data are too meager to locate such possible islands, or to furnish evidence of thinning in the Hunton on the flanks of such possible positive areas.

CLAY COUNTY

Stratigraphy.—In eastern Clay County Scow Brothers' Gates well No. 1 (SE. ¼, SW. ¼, Sec. 16, T. 9 S., R. 4 E.) reveals 323 feet of Hunton dolomitic limestone, chert, and sand (well No. 3, cross section *AA'*, Fig. 10). The three chert-bearing strata of Riley County are present, but proportions of chert in the samples are somewhat reduced. About 200 feet in the upper and middle parts of the section show large amounts of subrounded to subangular, clear to slightly frosted sand grains. This section corresponds with the upper limestone and middle cherty zones of Riley County. If these two zones do lie respectively above and below the Siluro-Devonian contact, as previously suggested, the sand is probably derived from a landmass which was exposed during the interval following Silurian deposition. The crystalline oölite or lower limestone zone occurs between depths of 2,385 and 2,401 feet in the Gates well, and is associated with minor amounts of light tan, rough to smooth chert.

The Hunton section thins to 272 feet in the Derby Oil Company's Neimoller well No. 1 (NW. ¼, SW. ¼, Sec. 19, T. 10 S., R. 3 E.), about 10 miles southwest of the Gates test. The lower cherty zone is missing, as is also the still lower crystalline oölite zone, suggesting that through overlap the basal Hunton of this region is younger than that on the northeast. At the top of the section there is considerable sand, but the upper cherty zone is gone, perhaps as a result of offlap.

Structure.—Siluro-Devonian beds in Clay County dip and thin toward the southwest. Part of the thinning results from progressive disappearance of uppermost and lowermost Hunton strata, a trend which continues southwestward across the Salina basin. If there exists an erosion interval within the Hunton beds, that break may also partly account for thinning of the strata. In Hunton time the site of Clay County probably was inundated by seas which advanced from the northeast and withdrew in the same direction, leaving beds with gentle

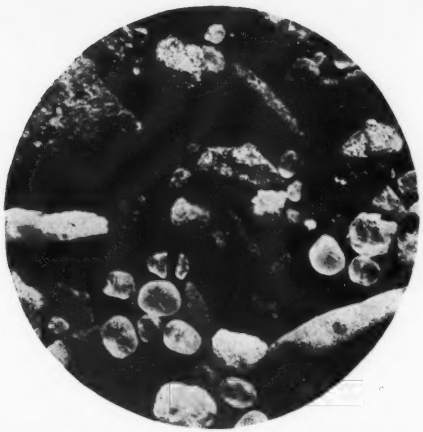
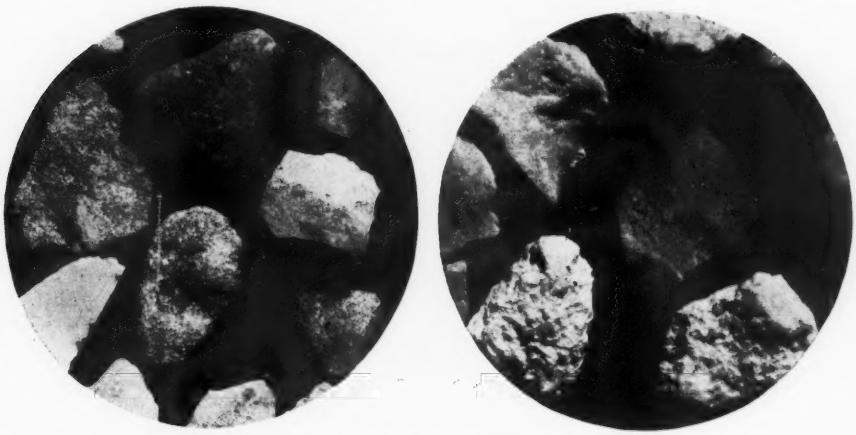
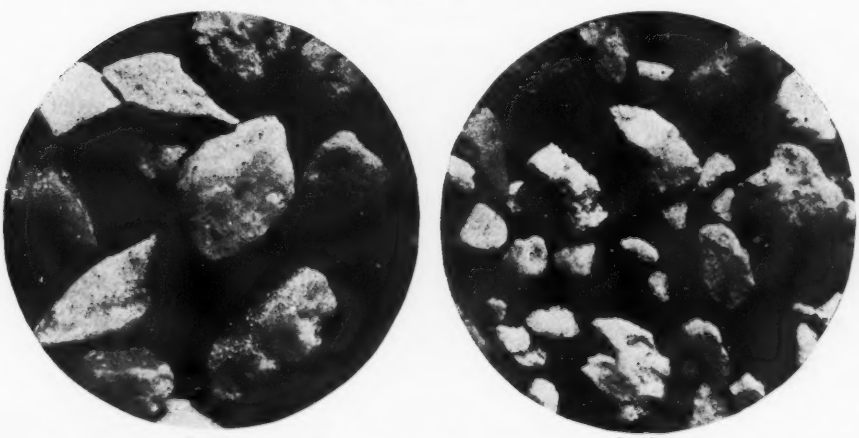


FIG. 3.—Photomicrograph (×10) of sand, shale, and dolomite from Misener sandstone horizon. Shale is Chattanooga cave. Stark well No. 1, Sec. 12, T. 25 S., R. 2 E., depth 3,190–3,192 feet.



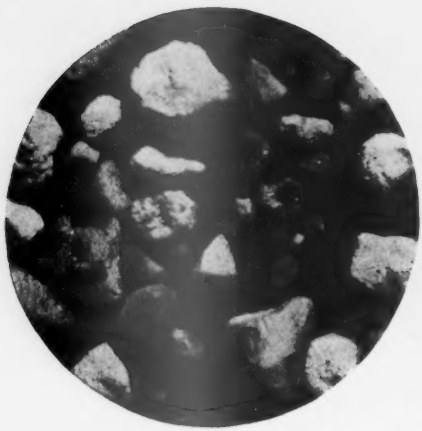
Sample Residue

FIG. 5.—Photomicrographs (×10) of upper cherty zone in the Hunton limestone. Parks well No. Sec. 16, T. 10 S., R. 8 E., Riley Co., depth 1,300-1,310 feet.



Sample Residue

FIG. 6.—Photomicrographs (×10) of middle cherty zone in Hunton limestone. Parks No. 1, depth 1,490–1,500 feet.



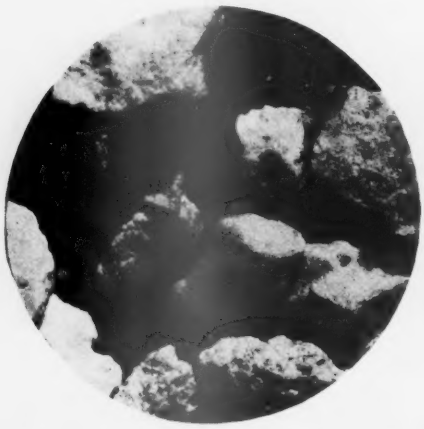
Sample

Residue

FIG. 7.—Photomicrographs (×10) of lower cherty zone in Hunton limestone. Parks well No. 1, Sec. 16, T. 10 S., R. 8 E., Riley Co., depth 1,640–1,650 feet.

FIG. 8.—Photomicrograph (×10) of typical Hunton crystalline dolomitic limestone. Umscheid well No. 1, Sec. 32, T. 8 S., R. 9 E., Pottawatomie Co., depth 1,520–1,525 feet.

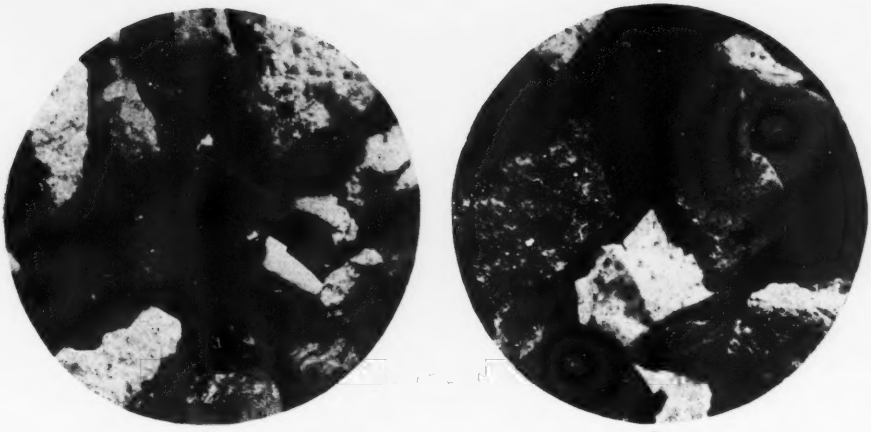
FIG. 9.—Photomicrograph (×10) showing roughly spherical, crystalline, dolomitic oölite-like aggregates of basal Hunton strata in Salina basin. Umscheid No. 1, 1,638–1,644 feet.



Sample

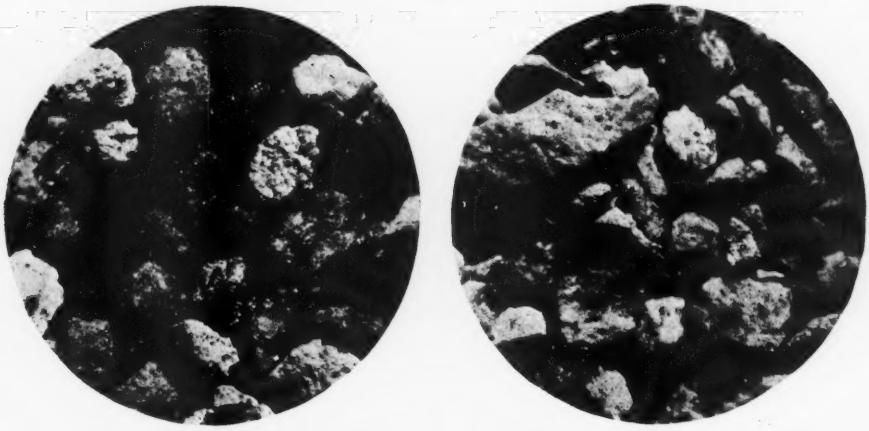
Residue

FIG. 17.—Photomicrographs (×10) of typical light tan and gray chert and limestone which is widespread in Hunton of south-central Kansas. Boller well No. 1, Sec. 29, T. 24 S., R. 1 E., Harvey Co., depth 3,500–3,504 feet.



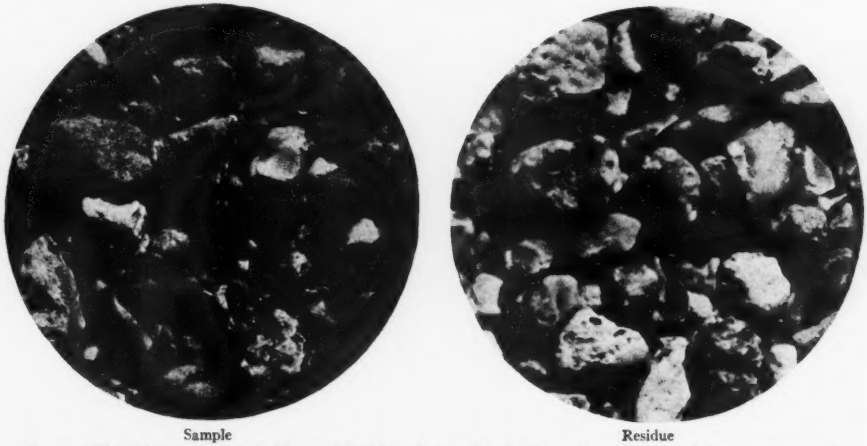
A B

FIG. 18.—Photomicrographs (×10) of residues of uppermost zone in Hunton limestone of southern McPherson Co.
A. Note subrounded sand grain and dark (red) chert fragment near center of picture. Chavez well No. 4, Sec. 20, T 21 S., R. 1 W., depth 3,308–3,313 feet.
B. Note dolocastic pyrite-bearing chert. Huxman well No. 10, Sec. 29, T. 21 S., R. 1 W., depth 3,265–3,270 feet.



Sample Residue

FIG. 19.—Photomicrographs (×10) of middle zone in Hunton limestone of southern McPherson Co. Note light to medium brown aggregates of crystals and dolomite rhombs in sample, and light tan dolocastic chert in residue. Huxman well No. 9, Sec. 29, T. 21 S., R. 1 W., depth 3,257–3,263 feet.



Sample Residue

FIG. 20.—Photomicrographs (×10) of brown dolomitic and unevenly colored gray cherty limestone in lowermost zone of Hunton in southern McPherson Co. From Huxman well No. 9, depth 3,278–3,280 feet.

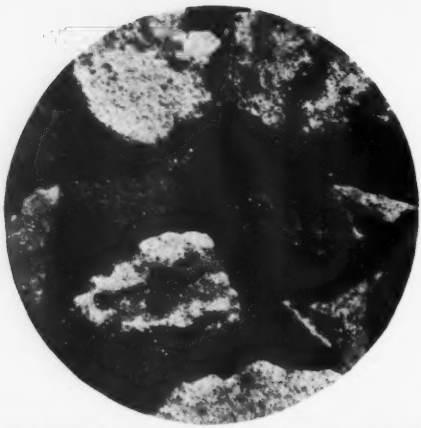
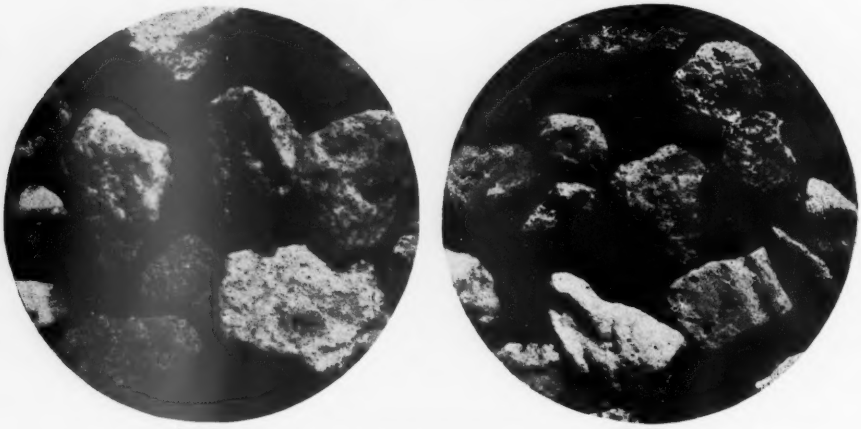


FIG. 21.—Photomicrograph (×10) showing brown dolomite crystals intertonguing with light tan rough chert. From the Harrison well No. 1, Sec. 23, T. 25 S., R. 2 E., Sedgwick Co., depth 3,195–3,205 feet.



Sample Residue

FIG. 22.—Photomicrographs (×10) of the cherty light tan dolomitic limestone of Hunton of Butler Co. Note dolocasts in residue. Phillips well No. 1, Sec. 17, T. 24 S., R. 4 E., depth 2,785–2,795 feet.

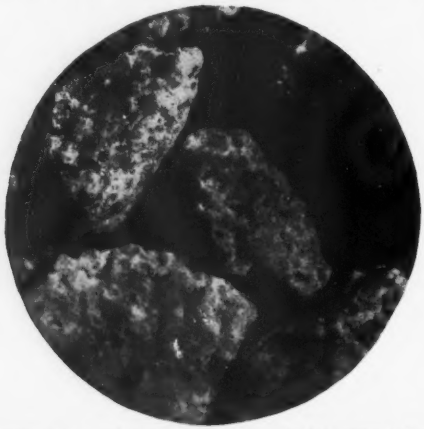


FIG. 23.—Photomicrograph (×10) of colorless sand grains embedded in Hunton limestone. Schroeder well No. 3, Sec. 36, T. 22 S., R. 5 W., Reno Co., depth 3,805–3,815 feet.

northeast dips which later were reversed by the late Paleozoic rise of the Nemaha arch.

NORTHERN DICKINSON COUNTY

Stratigraphy.—In northern Dickinson County lowermost Hunton strata progressively disappear toward the west. The upper part of the section, possibly Devonian in age, thins toward the west, apparently because of erosion or nondeposition within the section rather than disappearance of uppermost beds. The Carter Oil Company *et al.* Hebner well No. 1 (NW. ¼, SE. ¼, Sec. 31, T. 13 S., R. 3 E.) reveals 270 feet of Hunton strata logged as follows.

LOG OF CARTER OIL COMPANY'S HEBNER NO. 1, SEC. 31, T. 13 S., R. 3 E.

Depth (Feet)	*Description of Zones*
2,590	TOP OF HUNTON
2,590–2,620	UPPER CHERTY ZONE. About 50 per cent light tan or grayish white microfossiliferous smooth to rough surfaced chert, and 50 per cent grayish tan crystalline dolomitic limestone
2,620	TOP OF UPPER LIMESTONE ZONE
–2,640	Light tan crystalline dolomitic limestone
–2,650	About 80 per cent light tan crystalline dolomitic limestone and 20 per cent angular sand
–2,670	Light to medium brown crystalline dolomitic limestone
–2,680	About 90 per cent light to medium brown crystalline dolomitic limestone, and 10 per cent angular sand
–2,790	Light tan or grayish tan crystalline dolomitic limestone
2,790	BASE OF UPPER LIMESTONE ZONE
–2,830	MIDDLE CHERTY ZONE. Mostly grayish tan crystalline dolomitic limestone, but some samples contain up to 50 per cent light gray, tan, or white rough chert
2,830	TOP OF MIDDLE LIMESTONE ZONE
–2,840	Medium gray crystalline dolomitic limestone
–2,860	Mixture of light tan dense dolomitic limestone, brown or gray crystalline dolomitic limestone, light tan chert, gray shale and pyrite
2,860	UNCONFORMITY AT BASE OF MIDDLE LIMESTONE ZONE. Base of Hunton

In northern Dickinson County the lower cherty and crystalline oölite zones of Pottawatomie and Riley counties appear to be gone, and the middle cherty zone occurs nearer the base of the section. It is thinner here than in Riley County, and the chert normally is somewhat smoother-surfaced, sharper-edged and less dolocastic, but the light tan or white color and microfossiliferous nature are unchanged.

In some wells at the bottom of the Hunton section there is a thin bed containing some rough-surfaced, gray or tan, somewhat dolocastic chert. Residues show that the dolocasts are partially filled with quartz, the replacement in some pieces being sufficiently complete to obliterate much of the dolocastic space, leaving the chert with a rough surface. Some pieces contain dark-colored specks of pyrite. This is regarded as a local chert which formed above the unconformity at the base of the Hunton.

Some beds contain as much as 20 per cent subrounded to subangular, clear or slightly frosted sand, mixed with crystalline dolomitic limestone. In one hole, Marshall and Hennesy's Danz well No. 1 (NW. ¼, Sec. 34, T. 11 S., R. 4 E.), the sand comprises as much as 50 per cent of some samples. Of the Dickinson

County wells studied, this Danz test is nearest the Riley and Clay County wells which show exceptional percentages of sand in Hunton samples. This may be corroborative evidence that in or near what is now Riley County there was in Hunton time a land area supplying sands to Hunton seas. Conversely, some of the sand may be cave from higher strata.

Pyrite occurs throughout the section, but is most abundant in two zones, one near the top just beneath the contact with the overlying Chattanooga shales, the other near the bottom just above the contact with the Maquoketa-Sylvan shales. These pyrite zones occur at unconformities. Perhaps the intraformational pyrite also has stratigraphic significance, which more detailed work may later reveal.

Structure.—In Dickinson County, as in the area on the northeast, Hunton strata dip gently and thin gradually west and southwest. An arch crosses the northern part of the county, but additional wells giving further control are needed to delimit closely the structure.

SOUTHERN DICKINSON AND WESTERN MORRIS COUNTIES

Stratigraphy.—Hunton strata are thinner and cherty zones less prominent in this area than in the region on the north. The section consists largely of buff to gray, crystalline dolomitic limestone. Minor amounts of chert appear in some beds. Madison, Fisher and Lauck's Brockmeier well No. 1 (NW. $\frac{1}{4}$, SE. $\frac{1}{4}$, Sec. 6, T. 16 S., R. 5 E.) reveals 185 feet of Hunton (well No. 10, cross section *BB'*, Fig. 11) logged as follows.

LOG OF MADISON, FISHER, AND LAUCK'S BROCKMEIER NO. 1, SEC. 6, T. 16 S., R. 5 E.

Depth (Feet)	*Descriptions of Zones*
2,465	TOP OF HUNTON. UPPER LIMESTONE ZONE
2,465–2,495	Gray or tan, dense to crystalline dolomitic limestone
–2,500	Dolomitic limestone as above, plus small amounts of pyrite and angular quartz sand (erosional zone?)
–2,530	Very light tan or gray crystalline dolomitic limestone
–2,540	Dolomitic limestone as above, plus small amounts of pyrite (erosional zone?)
–2,575	MIDDLE CHERTY ZONE. Largely light gray or tan finely crystalline dolomitic limestone. Chert constitutes up to 20 per cent of samples, and is of two principal types: (1) white rough frosty and sparingly microfossiliferous, (2) light gray or tan and smooth. Both are non-dolocastic
–2,615	MIDDLE LIMESTONE ZONE. Light gray finely crystalline dolomitic limestone. A little pyrite in lowest 5 feet
–2,625	LOWER CHERTY ZONE. Light gray buff or tan, dense to finely crystalline dolomitic limestone, with a little brown or gray rough chert
–2,640	LOWER LIMESTONE OR CRYSTALLINE OÖLITE ZONE. Gray crystalline dolomitic limestone with some rounded aggregates. Traces of pyrite and brown rough chert near base
–2,650	EROSIONAL ZONE. About 50 per cent gray or tan, dense to finely crystalline dolomitic limestone, and 50 per cent gray rough moderately dolocastic chert
2,650	BASE OF HUNTON BEDS

If interpretations in the foregoing log are correct, the upper cherty zone of areas on the north and east is missing. Also several of the zones are thinner. Pyrite bands within or between zones may mark erosional breaks. One such small concentration of pyrite occurs just above the middle cherty zone, which is the

horizon proposed as the possible contact between Silurian and Devonian beds in the area on the north and northeast.

Chert within the Hunton diminishes toward the west. This tendency is well shown in the Prairie Oil and Gas Company's Rumbolt well No. 1 (SW. ¼, NE. ¼, Sec. 12, T. 16 S., R. 2 E.), where the Hunton section comprises about 250 feet of buff crystalline dolomitic limestone, with chert occurring only in the lower part of the section and in minor amounts.

Structure.—Siluro-Devonian strata dip west and southwest, and thin gradually in the same directions, except in central Morris County where thinning occurs toward the east on the flanks of the Nemaha arch as a result of erosion during uplift of that structure.

NORTHERN MARION COUNTY

Stratigraphy.—In northern Marion County as in southern Dickinson County Hunton strata contain comparatively little chert, but there is some calcitic limestone instead of the nearly ubiquitous dolomitic limestone of more northern areas. The change from dolomitic to calcitic limestone is not confined to definite beds which can be traced with certainty from well to well, but rather it occurs in different parts of the section in different places. For example, strata may be completely calcitic as in the upper part of the Arkansas Fuel Company's Hacker well No. 1 (NW. ¼, NE. ¼, Sec. 6, T. 17 S., R. 1 E.), or completely dolomitic as in the upper part of the White Eagle Oil and Refining Company's Ucker test No. 1 (NE. ¼, NW. ¼, Sec. 24, T. 17 S., R. 2 E.). Also, some wells show a mixture of dolomitic rhombs and crystals in a calcitic cement. More calcitic limestone occurs in the Hunton of northwestern Marion County than in the section farther east.

The crystalline oölite layer appears in samples from the basal Hunton in the Hacker well No. 1 between the depths of 3,165 and 3,175 feet, but is missing from many Marion County holes. Basal Hunton beds were probably deposited on an uneven surface, and are not everywhere the same age. In most wells this crystalline oölite zone is missing because the early Hunton sea in which it was deposited covered only limited parts of central Kansas.

No evidence of an unconformity within the Hunton strata of northern Marion County was observed, and all beds are tentatively placed either in or below the middle cherty zone. This accords with views previously expressed that only the lower part of the Riley County section extends southward. But uppermost Hunton strata in northern Marion County are not everywhere the same in age. In some areas a thin chert-bearing bed which resembles the middle cherty zone of more northern areas lies just beneath the Chattanooga shale, but in most holes this chert is missing, perhaps because of erosion.

Structure.—Siluro-Devonian sediments thin southward, and disappear in northern Marion County (Fig. 1). A north-south section across this area (Fig. 11) shows little if any basin structure in Hunton rocks. Structurally, beds occur

lower and lower in a southerly direction, and finally disappear in Townships 18 and 19 South.

NORTHEASTERN MCPHERSON COUNTY

Stratigraphy.—Hunton strata in northeastern McPherson County resemble those in northern Marion County. They consist largely of tan or gray, crystalline dolomitic and calcitic limestone, intermixed with small amounts of shale, and microfossiliferous light gray or frosty white, smooth to somewhat rough chert. The calcitic limestone layers occur preponderantly in wells near the periphery of the area of Hunton beds, whereas wells farther from the edge, and hence probably farther from the old Hunton shoreline, show sections composed largely of dolomitic limestone. Sand is present in some samples, and is considered the result of weathering and erosion which occurred near the shore of the Hunton sea.

Chert is not found in all wells, but if present it ordinarily occurs at or near the top of the section. For example, in the Broadwater *et al.* Heaton well No. 1 (SE. ¼, SE. ¼, Sec. 28, T. 17 S., R. 1 W.) there are about 75 feet of Hunton strata, with the top at 3,027 feet. Chert comprises up to 25 per cent of samples between 3,027 and 3,055 feet, and is believed equivalent to the middle cherty zone of areas on the northeast. Below 3,055 feet strata consist of dolomitic and calcitic crystalline limestone. Tentatively this entire section is placed below the horizon previously suggested as the possible site of an erosional break within Hunton strata.

Structure.—Siluro-Devonian beds thin and disappear in northeastern McPherson County. They appear to extend farthest southwest in T. 19 S., R. 3 W., on the crest of the Voshell anticline (Fig. 2), suggesting that this part of the site of the anticline was once a trough or bay receiving sediments. It is possible that the outline reflects a minor natural irregularity which is without special structural significance.

SALINE COUNTY

Stratigraphy.—Hunton strata occur in all but the southwestern part of Saline County. A typical section for this area is shown by the Kinney *et al.* Beil well No. 1 (center of NW. ¼, Sec. 23, T. 14 S., R. 5 W.) logged as follows.

LOG OF KINNEY ET AL. BEIL NO. 1, SEC. 23, T. 14 S., R. 5 W.

Depth (Feet)	*Descriptions of Zones*
3,595	TOP OF HUNTON
–3,618	MIDDLE CHERTY ZONE. Light tan, finely crystalline to dense, calcitic and dolomitic limestone, with up to 50 per cent light tan smooth or slightly rough chert
–3,645	Light tan, buff or brown, dense to finely crystalline calcitic limestone
–3,680	Medium gray finely crystalline dolomitic limestone, with up to 20 per cent dirty gray and rough chert. A little angular quartz sand appears in lowest 10 feet of samples
3,680	BASE OF HUNTON

At or near the top of the section in most wells in this area a light tan or light gray, smooth to slightly rough, sparingly dolocastic and somewhat microfossiliferous chert is mixed with a tan to brown crystalline dolomitic limestone. The

writer considers this the middle cherty zone. If this is correct, then here, as in areas at the northeast, upper Hunton strata are missing, and possibly only beds of Silurian age are present.

In some wells a little tan or brown, crystalline or flaky calcitic limestone is mixed with the dolomitic middle cherty zone, and a calcitic limestone normally occurs beneath this zone. Such calcitic limestones are thicker in the Hunton section of southern Saline County than farther north. This accords with trends previously noted that beds in the southwestern part of the Salina basin contain comparatively more calcitic and less dolomitic limestone than in regions on the northeast.

A dirty gray to light tan, rough to smooth, microfossiliferous chert, mixed with gray or tan crystalline dolomitic or calcitic limestone commonly lies at the base of the Hunton section. It is a basal chert and does not occupy the same stratigraphic position in all wells. It is not considered of regional significance for correlation purposes.

Structure.—Hunton strata thin and disappear on the outer flanks of the Central Kansas uplift. Post-Hunton rise of the uplift probably caused some truncation of Hunton beds. However, Lee[11] has shown in an isopach map that the thickest Mississippian limestone section in north-central Kansas occurs in northern Saline County; hence, any truncation of Hunton strata must have occurred prior to Mississippian deposition.

Contours on top of the Hunton (Fig. 2) reflect an anticlinal structure which trends northeast and southwest across southeastern Saline County. Intensity of the folding diminishes toward the northeast.

NORTHEASTERN ELLSWORTH COUNTY

Stratigraphy and structure.—The edge of Hunton beds west of Saline County is uncertain. They are absent in southern and central Ellsworth County, but north of there available samples do not permit accurate location of the boundary. Revisions of the maps accompanying this paper will be necessary when more information is available.

OTTAWA COUNTY

Stratigraphy.—Examination of the comparatively few available samples from Ottawa County indicates that the Hunton has thinned from the northeast; over most of the county it is less than 200 feet thick, and in the southwestern part is perhaps less than 100 feet. Buff-colored crystalline dolomitic limestone comprises most of the section, with some frosty white to light tan chert in the upper part. This chert resembles the middle cherty zone of areas on the east, but distances between wells preclude certainty of correlations.

Above the Hunton there is as much as 50 feet of subrounded to angular sand

[11] Wallace Lee, "Subsurface Mississippian Rocks of Kansas," *Kansas Geol. Survey Bull. 33* (1940). 114 pp.

mixed with minor amounts of limestone and shale. Areal extent of these sandy beds is unknown. They may have formed near the shores of a Hunton sea which on the east was depositing limestones, but in the absence of evidence on their age they are best assigned to the Misener sandstone. The source of the sands probably was the Central Kansas uplift on the west and southwest.

Structure.—In this, the western part of the Salina basin, there is little evidence in Hunton strata of upturning on the flanks of the Central Kansas uplift (Fig. 10). Had differential upward movement between the uplift and the basin been of major proportions subsequent to Hunton time it should be reflected in upturned strata, even though Hunton beds may never have overlapped far onto the uplift. Absence of such upturning indicates that the Central Kansas uplift was a relatively stable platform in Hunton and later geologic time.

MITCHELL AND LINCOLN COUNTIES

Stratigraphy and structure.—Available wells in Mitchell and Lincoln counties do not assure certainty of correlations. Samples indicate the Hunton formation is about 100 feet thick in eastern Mitchell and Lincoln counties, but thins and disappears in the central or western part (wells No. 7 and No. 8, cross section *AA'*, Fig. 10). The beds appear to be similar to those in Ottawa County, with the middle cherty zone lying near the top of the section, and buff to brown crystalline dolomitic limestone forming the lower part. Only small amounts of sand separate the Hunton limestone and the overlying Chattanooga shale.

HUNTON STRATA IN SOUTH-CENTRAL KANSAS

GENERAL SURVEY

Correlation problems.—A minimum of about 12 miles separates the Hunton limestone along the south edge of the Salina basin from a limestone section in south-central Kansas (Fig. 1) which the writer calls Hunton, and considers of similar Siluro-Devonian age. However, some geologists believe there are no Hunton rocks in central Kansas south of the Salina basin, and place this southern limestone section in the post-Hunton Kinderhook shale. The uncertainty arises principally because fragments of spore-bearing shale, believed to be Kinderhook in age, occur in samples gathered below the limestone. Also occurring in such samples are fragments which appear to come from several Pennsylvanian and Mississippian formations, and the author considers these, together with the spore-bearing shale, to be caved pieces.

Cores might aid in solution of this problem, but they are unknown. Alternatively, if the limestone can be traced laterally into known beds its stratigraphic relationship will be determined. This the writer has attempted to do. Three cross sections (Figs. 13, 14, 15) are presented. One of these (Fig. 15) carries the beds eastward over the Nemaha arch into what the writer believes are Hunton strata east of that structure in Butler County. However, correlations do not go north-

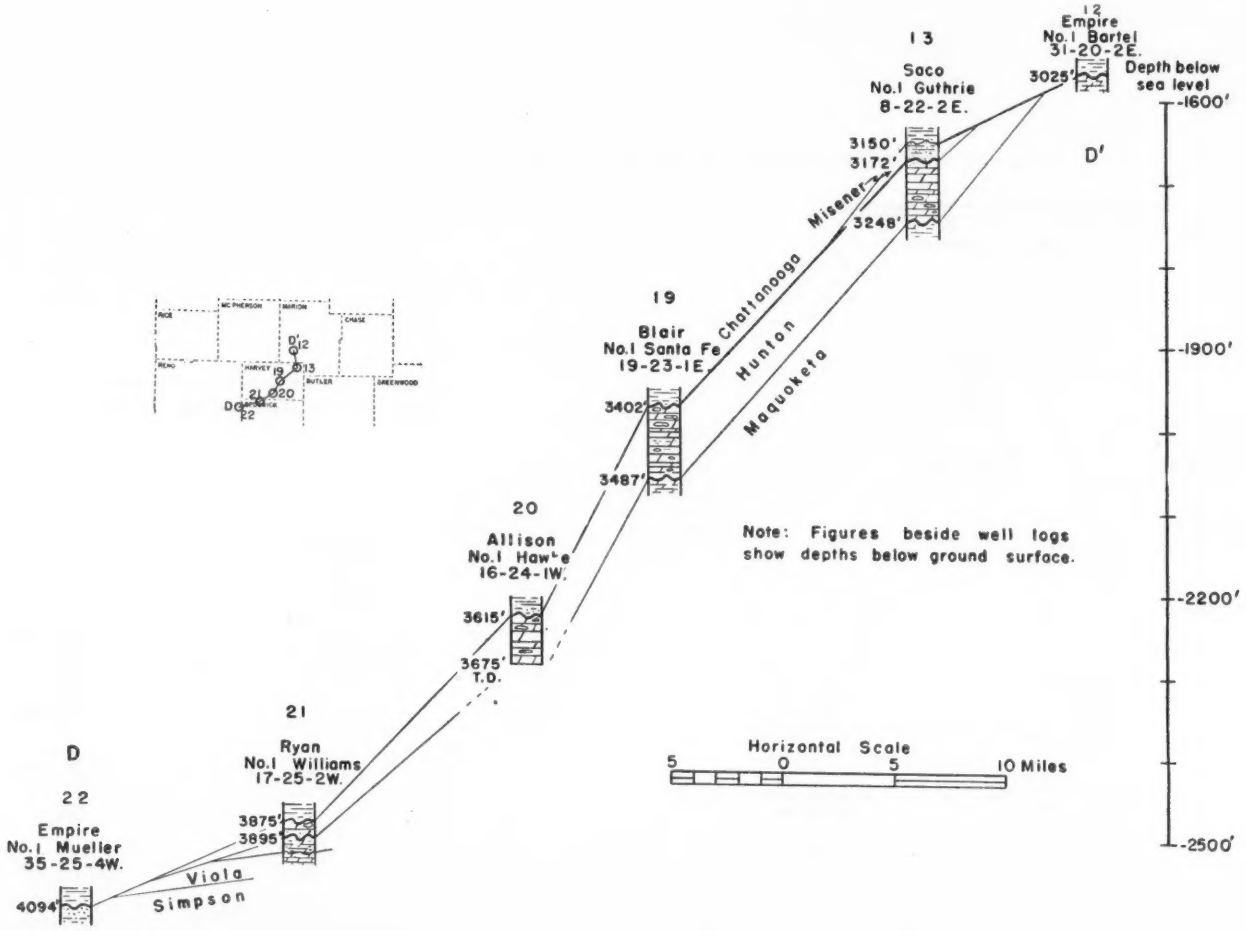


FIG. 13.—Geologic cross section of Hunton strata along line *DD'* (see inset index map) in south-central Kansas.

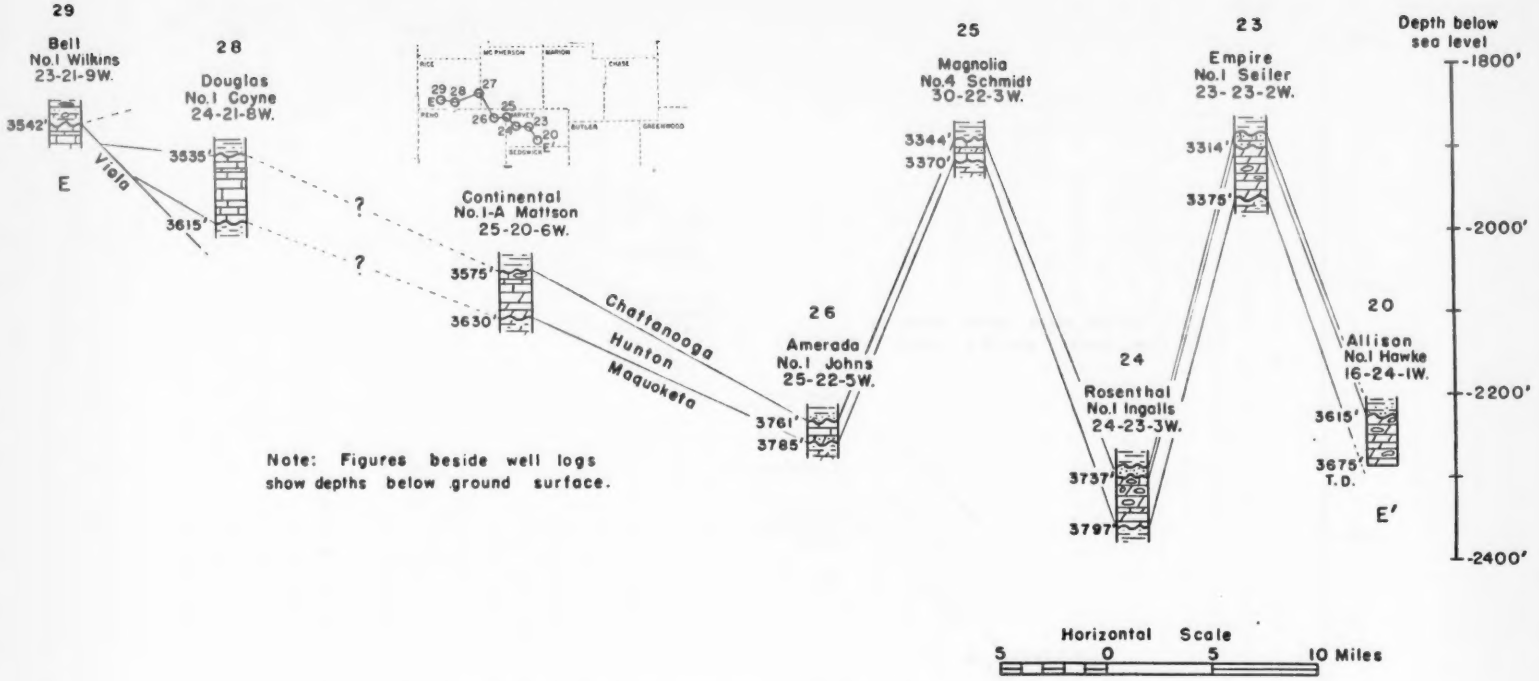


FIG. 14.—Geologic cross section of Hunton strata along line *EE'* (see inset index map) in south-central Kansas.

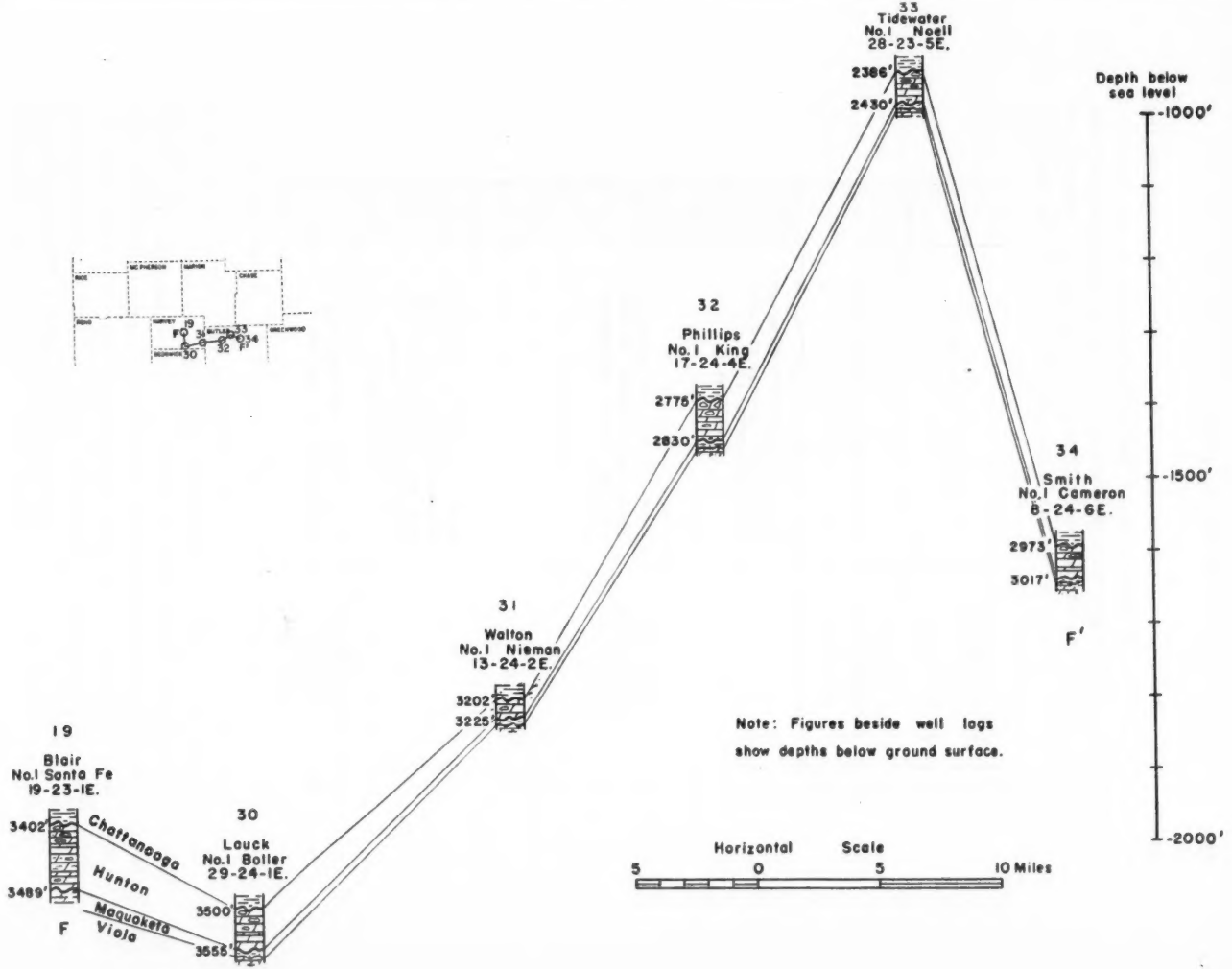


FIG. 15.—Geologic cross section of Hunton strata along line *FF'* (see inset index map) in south-central Kansas.

ward to connect with known Hunton beds of Pottawatomie County, and the Hunton age of the Butler County beds is questioned by some.

Stratigraphy.—Lithologic variations exist between Salina basin Hunton strata and the beds of south-central Kansas, although both sections are primarily of limestone (Fig. 16). More chert occurs in the southern area, and the limestone

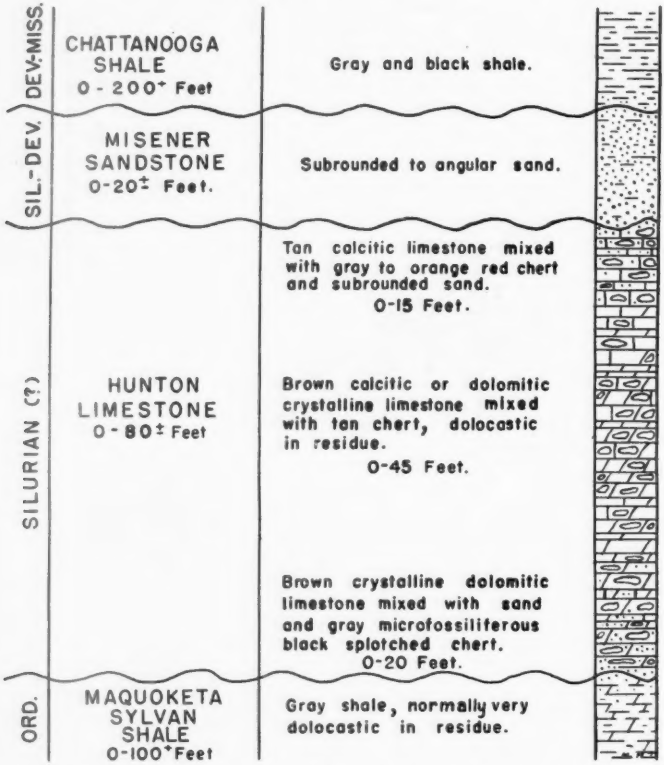

DEV.-MISS.
CHATTANOOGA SHALE
0 - 200+ Feet
Gray and black shale.
SIL.-DEV.
MISENER SANDSTONE
0-20± Feet.
Subrounded to angular sand.
Tan calcitic limestone mixed with gray to orange red chert and subrounded sand.
0-15 Feet.
SILURIAN (?)
HUNTON LIMESTONE
0 - 80± Feet
Brown calcitic or dolomitic crystalline limestone mixed with tan chert, dolocastic in residue.
0-45 Feet.
Brown crystalline dolomitic limestone mixed with sand and gray microfossiliferous black splotched chert.
0-20 Feet.
ORD.
MAQUOKETA SYLVAN SHALE
0-100+Feet
Gray shale, normally very dolocastic in residue.

FIG. 16.—Generalized geologic column of Hunton formation in south-central Kansas.

there is less dolomitic and more calcitic. Furthermore, some cherts in south-central Kansas are irregularly splotched with gray, black, or pure white patches, whereas cherts in the Salina basin are of more uniform white, light gray or light tan color. But there also are similarities. The most widespread chert of the south central Kansas Hunton is a tan, rough porous to smooth solid variety (Fig. 17), dolocastic in residues, which resembles Salina basin Hunton cherts, especially the type occurring in the middle cherty zone of that area. Correlations can not be considered certain, but it is suggested that the Hunton of south-central

Kansas may be the same age as the middle cherty and middle limestone zones of the Salina basin. If the Siluro-Devonian contact lies above the middle cherty zone of the Salina basin, and if the correlation here suggested is correct, it follows that the south central Kansas Hunton is of Silurian age.[12]

Structure.—Hunton beds are nearest the ground surface in the region of the Nemaha ridge (Fig. 2). They are missing locally just west of the ridge in Butler County, but are believed present in the area east of that structure. They are of relatively uniform thickness (Figs. 13, 14, 15), and dip gently west (except near local structures) until reaching southwestern McPherson and northeastern Reno counties. They disappear altogether in southern or southeastern Rice County.

In northern Sedgwick County (T. 25 and 26 S.) and in northwestern Butler County (T. 25 S., R. 3 E. to T. 23 S., R. 5 E.) the Hunton overlaps the Maquoketa-Sylvan shale and lies directly on Viola limestone. The unconformity is marked by a thin gray remnant of shale, or an exceptional abundance of pyrite in a section which otherwise is limestone and chert. Unless samples are gathered at close intervals the break may go unnoticed. The unconformity zone occurs over wide areas, and can be traced northward until it merges with the Maquoketa-Sylvan shale. Farther west, however, in Reno County the Maquoketa-Sylvan shale continues south of the Hunton formation.

The Empire Oil and Gas Company's Robinson well No. 1 (SE. ¼, NE. ¼, Sec. 29, T. 25 S., R. 4 E.) shows Hunton strata lying on Simpson sand, with Maquoketa-Sylvan and Viola strata missing. Farther south, outside the area of this report, the Viola commonly is missing, and Hunton strata rest on the Simpson. Such structural relationships indicate that post-Simpson but pre-Hunton uplift occurred in the region.

Paleogeography.—Some geologists have considered the southern Kansas Hunton area an outlier of Salina basin beds; but the marked lithologic variations within a few miles in contrast with Salina basin beds which generally do not show much change over scores of miles suggests that the two regions may never have been connected directly. Rather the deposits may have formed in two bays of the Hunton sea which filled the area at the northeast, and may have extended independently into central Kansas from the east. Under such conditions fossils of the two regions might be identical, but varying sedimentary conditions in the two bays might cause deposition of somewhat different sorts of chert and limestone, especially in edge or shore deposits.

SOUTHERN MCPHERSON COUNTY

Stratigraphy.—Two layers can be recognized in samples from wells penetrating a complete Hunton section in southern McPherson County. There is an

[12] Hugh W. McClellan (*Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 12 (December, 1930), p. 1545) reported that fossil fragments recovered in a core of the Hege well No. 1 (SE. ¼, NW. ¼, SE. ¼, Sec. 13, T. 22 S., R. 2 W.), Harvey County, at 3,397 to 3,400 feet had been identified by R. C. Moore, Kansas State geologist, as "not Kinderhook, and probably Silurian rather than Devonian." These fossils came from the limestone which is called Hunton in this paper.

upper light tan crystalline calcitic limestone, and a lower brown, gray or tan crystalline dolomitic limestone. However, careful study and clean samples permit the delineation of three zones instead of two in all but edge wells of the area. Residues reveal these three zones more distinctly than do ordinary samples.

The *uppermost zone*, called the "white Hunton" by some oil geologists, is a calcitic limestone containing up to 20 per cent insoluble material, which consists of sand and chert (Fig. 18). The limestone is light tan crystalline and largely calcitic, but partially dolomitic in some wells. The sand is angular to subrounded, and occurs near the unconformity above the Hunton. Chert forms most of the residues, and is of various sorts. At the top of the zone there are three kinds—a smooth light gray microfossiliferous variety, a porous gray dolocastic rough pyrite bearing form (Fig. 18 B) which is the weathered counterpart of the smooth gray variety, and a red, orange-red, or reddish yellow somewhat rough type (Fig. 18 A) which, except for hardness, resembles iron-stained rock salt with rough edges rounded by moisture. These cherts exist lower in the zone, but there they are largely superseded by a light tan and light gray unevenly colored slightly rough form which in places is microfossiliferous. In residues this chert is sparingly dolocastic.

The *middle zone*, which forms the upper part of the beds called "brown Hunton" by some geologists, is a calcitic limestone in a few wells near the north edge of the Hunton, but elsewhere is dolomitic and cherty. The chert (Fig. 19) is light tan or light gray, rough and moderately dolocastic in residues. It constitutes as much as 35 per cent of the original sample in some wells. The limestone (Fig. 19) is light to medium brown, and sugary to minutely crystalline or even dense. Aggregates of crystals are common, and contain some dolomite rhombs. This zone is differentiated from overlying beds by its chert and dolomitic limestone, and from underlying beds by its chert alone since the brown dolomitic limestone continues downward unchanged. A few chert fragments are porous and easily crushed with a knife blade. In some residues the dolocasts are rough-edged and partly filled with light tan chert. Indistinct microfossils occur sparingly, and are embedded in the chert. Silicified macrofossils are rare, as are also black or dark gray spots within the chert, two features which are common in the underlying gray chert zone. Near the base the chert becomes less common, and clear angular to subrounded sand increases in abundance.

The *lowermost zone*, which is the lower part of the "brown Hunton," is predominantly brown dolomitic limestone (Fig. 20) much like that in the overlying zone, except that it is somewhat finer-grained. However, up to 20 per cent of this limestone in some wells is a brown finely crystalline calcitic limestone which if not tested is easily confused with the dolomitic material. Furthermore, the aggregates of dolomite crystals effervesce rather freely indicating that some of the cementing material is calcitic limestone. In residues (Fig. 20) the proportion of insoluble material is less than in the overlying tan chert zone, ordinarily not exceeding 20 per cent. The chert is predominantly light gray or light tan, but

many pieces are medium gray or black. Irregular flint-like splotches of darker colors are scattered about through lighter gray pieces. Dolocasts normally are not abundant. Microfossils are more numerous in this than in the overlying chert, and almost any residue will contain at least one poorly preserved gray chert crinoid columnal, bryozoan skeleton or other fossil fragment. Clear angular to frosted sub-rounded quartz sand comprises up to 30 per cent of residues though ordinarily it is not this abundant. Inclusions of quartz grains in the chert are common.

The Continental Oil Company's Goering well No. 11 (NW. corner, SW. ¼, Sec. 29, T. 21 S., R. 1 W.), completed in 1939 for a potential of 350 barrels, shows the three Hunton zones described. Its log follows.

LOG OF CONTINENTAL OIL COMPANY'S GOERING NO. 11, SEC. 29, T. 21 S., R. 1 W.

Depth (Feet)	*Descriptions of Zones*
3,245	TOP OF HUNTON LIMESTONE
–3,265	UPPERMOST OR "WHITE HUNTON" ZONE. Light buff finely crystalline calcitic limestone with small amounts of chert
–3,283	MIDDLE ZONE. This is upper part of "brown Hunton." Brown crystalline dolomitic limestone with some tan chert which in residues is dolocastic
–3,296	LOWERMOST ZONE. Lower part of "brown Hunton." Brown crystalline dolomitic limestone with gray chert. Also a little calcitic limestone and (near base) subrounded sand grains
3,296	BASE OF HUNTON LIMESTONE

Structure.—The maximum thickness of the Hunton in southern McPherson County is a little more than 50 feet, with the thickest sections occurring in the southeastern part of the county. The beds continue over the crests of some anticlines, but are missing on other structural highs. For example, there are Hunton beds on the Voshell anticline in Harvey County (T. 22 S., R. 3 W.), but on the north in McPherson County along this same high the Hunton is missing in most wells.

HARVEY COUNTY

Stratigraphy.—An upper or "white Hunton" zone somewhat similar to that of southern McPherson County occurs in all but the southwestern part of Harvey County. The chert is light tan or white, rough to smooth, and dolocastic in residues. The limestone is both calcitic and dolomitic in the northern tier of townships (T. 22 S.) but largely dolomitic farther south. It is light tan or very light gray.

The middle and lowermost zones of southern McPherson County merge and form one lower or "brown Hunton" zone which covers Harvey County, and underlies the "white Hunton." The beds are largely brown crystalline dolomitic limestone with small amounts of light gray chert which may be equivalent to the black-splotched gray chert of the lowermost Hunton zone of southern McPherson County.

Over most of Harvey County the Hunton beds have a rather uniform appearance except for the contrast in tan and brown coloring (Fig. 17). The orange red and the black-splotched cherts of southern McPherson County are gone, and in

their places are uniformly colored light tan, gray, or white varieties. The limestones are tan or brown, crystalline, and somewhat resemble those of the Salina basin. The comparatively uniform nature of Harvey County beds suggests stable undisturbed conditions of deposition such as would exist in a sea some distance from land. Conversely, the variations in southern McPherson County, and the presence in the basal part of those beds of chert containing dirty gray flint-like splotches which may have formed under muddy turbulent conditions, suggest that the McPherson County area lay near the edge of a Hunton sea.

Exact correlations between Harvey and McPherson County cherts are uncertain; also, it appears doubtful that the contact between the upper light tan or "white Hunton" and the lower darker-colored or "brown Hunton" is everywhere at the same stratigraphic horizon. Color of the limestone is not considered a reliable means of correlation, and beds of two colors do not mean there was a break in deposition. It is considered likely that the south-central Kansas Hunton, which is of relatively uniform thickness, represents only one overlap of a Siluro-Devonian sea. Available evidence, though scant, favors a Silurian age.[13]

Structure.—Two major anticlinal trends, both of which are the sites of oil fields, cross Harvey County and cause many variations in the dip of Hunton beds (Figs. 2 and 14), which continue with undiminished thickness over the crests of the anticlines.

NORTHERN SEDGWICK COUNTY

Stratigraphy.—The light tan limestone associated with the upper or "white Hunton" zone of Harvey County is gone from most northern Sedgwick County wells, and there occurs only a brown dolomitic limestone mixed with tan, gray or white smooth to rough chert. In some wells the dolomitic limestone is coarsely crystalline, in others it is so fine that only reflection of innumerable pin points of light from tiny flat surfaces reveals its crystalline nature. Some fragments show the dolomitic layers interfingering with the chert bands in a manner somewhat resembling lit-par-lit injection in igneous rocks (Fig. 21). The chert itself is commonly lighter in color than the limestone, but some bands or spots are medium or dark brown. In a few residues it is non-dolocastic, but ordinarily it is pitted and even spongy. All gradations may occur in the same sample. Pyrite is sparingly disseminated through the chert, and causes darker specks and patches.

Structure.—Except over local flexures, Hunton beds in northern Sedgwick County dip toward the west. They disappear in the western part of the county.

SOUTHERN MARION COUNTY

Stratigraphy.—Hunton beds of southern Marion County consist of brown crystalline dolomitic limestone with interbedded bands of tan, smooth to rough, sharp-edged chert which in residues is dolocastic. A thin calcitic limestone occurs at the top of the section in a few wells. Samples from some holes in the south-

[13] Hugh W. McClellan, *op. cit.*

western part of the county contain dolomitic limestone but no chert. The Hunton, near its northern line of disappearance in T. 21 S., contains some gray and tan chert which is splotched with darker gray and black areas, and resembles a chert noted in the southern McPherson County area, which likewise was near a place where Hunton beds disappear.

Some do not agree that the Hunton strata of Harvey County continue eastward as far as shown on the writer's maps, but rather believe that the entire limestone and chert section below the Chattanooga shale belongs in Viola or older rocks. The writer's correlations are based primarily on similarity of lithologies, and the belief that there can be recognized an unconformity zone which represents the horizon at which Maquoketa-Sylvan beds occur farther west. The following log illustrates the foregoing interpretations.

LOG OF NATIONAL REFINING COMPANY'S URSCHEL NO. 4, SEC. 16, T. 21 S., R. 5 E.

Depth (Feet)	*Descriptions of Zones*
2,340	TOP OF HUNTON LIMESTONE
–2,345	About 75 per cent light gray to white rough chert, dolocastic in residues; and 25 per cent light buff dolomitic and light tan calcitic limestone. May be equivalent to the upper or "white Hunton" zone of Harvey County
–2,358	Same as at 2,340–2,345 feet except that the calcitic limestone is gone, and the dolomite crystals are grayer
–2,378	About 50 per cent light gray or brown dolomitic limestone, and 50 per cent chert as above
–2,390	UNCONFORMITY ZONE AT BASE OF HUNTON LIMESTONE. Largely dolomitic limestone, but up to 15 per cent angular sand. Some pyrite
Below 2,390	Dolomitic limestone, believed to be VIOLA

Structure.—Hunton strata occur close to the crest of the Nemaha arch, and are present in the region east of that structure. They are believed to occur in the McCoy *et al.* Borns well No. 1 in southwestern Chase County (NW. ¼, NE. ¼, Sec. 29, T. 22 S., R. 6 E.) below 3,035 feet, where a tan dolomitic limestone and a light tan smooth to rough chert below the Chattanooga shale are similar to beds called Hunton farther south in Butler County. Hunton beds are probably absent locally in T. 22 S., R. 4 E. (Fig. 2), since wells nearby in T. 23 S., R. 4 E., pass from Chattanooga shale into Simpson sand, but samples examined do not permit exact delimitation of this high.

BUTLER COUNTY

Stratigraphy.—In Butler County, as in the area west and north, the Hunton consists of brown crystalline dolomitic limestone mixed with light tan microfossiliferous rough to smooth chert which is usually dolocastic in residues (Fig. 22). In some wells a few feet of gray Maquoketa-Sylvan shale separate Hunton from Viola beds; in other holes the shale is missing, and the break is represented by some sand or pyrite in samples which are largely dolomitic limestone and chert.

Structure.—The Nemaha ridge passes through Butler County, and in places near the crest of the ridge Hunton strata are absent. They can be traced into the area east of that structure (Fig. 15) where their thickness is about the same as on the west. They are an oil reservoir in the Elbing pool centering in Sec. 17, T. 23 S., R. 4 E.

NORTHEASTERN RENO COUNTY

Stratigraphy.—Light to medium brown crystalline dolomitic and calcitic limestones mixed with light tan chert form the normal Hunton section of northeastern Reno County. Calcitic strata are more common in the upper parts of the section, and dolomitic in the lower parts. Sand grains are embedded in some limestone fragments (Fig. 23), and in wells near the Hunton's edge, sand is abundant.

In T. 22 S., R. 6 W., deposits consisting of sandy shale with minor amounts of dolomitic limestone are tentatively placed in the Hunton because they lie below the Chattanooga shale and above a dolomitic gray shale thought to belong in the Maquoketa-Sylvan formation. These beds are entirely different from the typical Hunton limestone on the east. They may represent a shore phase, or they may belong in the interval represented by the Misener formation. Lee[14] has shown that this area was the site of a drainage valley in Mississippian time, and the sandy shale may be the expression of a pre-Mississippian valley deposit.

Structure.—Hunton beds disappear in northern and eastern Reno County. The typical tan or brown chert-bearing dolomitic and calcitic limestone reaches only to R. 5 W. This may be the westernmost extent of Hunton beds, but on the northwest is a calcitic limestone of doubtful age, which will be considered in the Rice County discussion.

SOUTHEASTERN RICE COUNTY

Stratigraphy and structure.—The typical Hunton limestones and cherts of Harvey County may be present in the extreme southeastern part of Rice County. But on the west, in T. 21 S., R. 7 and 8 W. (Fig. 1), a non-cherty calcitic limestone up to 100 feet thick lies beneath Chattanooga shales and above a shale in which spores have been reported but which the writer suggests may be Maquoketa-Sylvan. The following log reveals the stratigraphic sequence in the area.

LOG OF GEAR ET AL. COYNE NO. 1, SEC. 24, T. 21 S., R. 8 W.

Depth (Feet)	*Descriptions of Zones*
3,447	BASE OF MISSISSIPPIAN LIMESTONES
−3,535	CHATTANOOGA SHALE
−3,615	About 80 per cent light gray crystalline calcitic limestone, 15 per cent dolomitic limestone and dolomite rhombs, and up to 5 per cent light gray smooth microfossiliferous chert and dark brown dolomitic shale. Age uncertain
−3,670	Gray micaceous fissile shale containing some angular to sub-rounded sand. Non-dolocastic in residues. Chattanooga spores have been reported in this shale (cave?)
−3,695	White or light tan coarsely crystalline calcitic limestone. Perhaps of Ordovician (Viola) age
−3,762	SIMPSON FORMATION. Principally sands and shales
3,762	TOP OF ARBUCKLE

Most oil geologists regard the questionable limestone as a local bed within the Chattanooga shale. If in Rice County Chattanooga spores[15] occur in the shale

[14] Wallace, Lee, *op. cit.* (1940), p. 27.

[15] Robert Carmody, of the Gulf Oil Company, states that in the Reese well No. 1 (Sec. 11, T. 26 S., R. 9 W.) limestone believed equivalent to the questionable limestone of southeastern Rice County was cored from 4,128 to 4,132 feet, and that black spore-bearing shale was cored from 4,132 to 4,137 feet. This well is about 25 miles from southern Rice County.

beneath the limestone its age certainly is post-Hunton. If the spores have resulted from caving, or if they are merely darker-colored fragments in the shale and not true Chattanooga spores they lose significance. The shale is non-dolomitic, and does not resemble the typical Maquoketa-Sylvan shale of areas farther east. If of that age it is near the edge of such deposits, and might differ in lithology from typical Maquoketa-Sylvan beds.

This questionable limestone apparently does not occur in wells in which a second limestone of definite Hunton age is present, although it is found only a few miles west of wells containing Hunton beds. The limestone is entirely calcitic and non-cherty, whereas known Hunton strata farther east are partially dolomitic and commonly but not everywhere cherty. However, the Hunton becomes more calcitic near its edges, and the differing lithologies of the beds prove nothing. The section is somewhat thicker than are Hunton strata on the east (Fig. 14).

In the most comprehensive study yet published of the Mississippian rocks of Kansas, Lee,[16] who examined samples from several wells in the area, reported no limestone in Mississippian shales. The Chattanooga was primarily a shale depositing epoch in Kansas. It is difficult to imagine conditions which would permit deposition of a thick local relatively pure limestone while shale was being laid down over such extensive adjoining areas. Conversely, it would be exceptional to find a thick Hunton bed in this area, since Hunton strata normally do not thicken toward the Central Kansas uplift. Cores of the limestone and underlying shale, taken from wells in southeastern Rice County, might reveal the age of these strata, but as far as is known none is available.

SUMMARY

Hunton strata thin from about 400 feet in the northeastern part of the Salina basin to zero on the outer flanks of the Central Kansas uplift. They dip gently toward the southwest except where local flexures cause reversal. Most of the beds are crystalline dolomitic limestones, but near the southern and western edges of the basin there are some calcitic beds. Three somewhat similar chert zones appear in the thickest sections. Correlation of these cherts over wide areas is not established beyond question; but it is believed that as Hunton strata thin toward the southwest the lowest cherty zone disappears because of overlap; the highest cherty band is gone, perhaps through offlap and erosion; and the middle cherty zone is the most widespread of the three. There is some evidence of a break in sedimentation above the middle cherty zone. If the Hunton in the Salina basin area is both Silurian and Devonian in age, this break may be the line between those two periods. There is also some evidence of erosional breaks of lesser extent at other horizons within the section.

At least 12 miles separate Salina basin Hunton beds and a limestone section

[16] Wallace Lee, *op. cit.* (1940).

on the south which is considered of similar Hunton age. These beds are cherty, dolomitic, and calcitic limestones with rather uniform total thicknesses of 30 to 60 feet. They extend into the region east of the Nemaha ridge, and probably are Silurian in age. Their lithology differs somewhat from Salina basin beds, suggesting they may never have been directly connected with those strata. It seems likely that the north and south-central Kansas Hunton sections were deposited in separate bays which extended into central Kansas from a larger seaway on the east.

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LATE PALEOZOIC AND EARLY MESOZOIC STRATIGRAPHY OF UINTA MOUNTAINS, UTAH[1]

HORACE D. THOMAS[2] AND MAX L. KRUEGER[3]
Laramie, Wyoming

ABSTRACT

At the western end of the Uinta Mountains, Triassic rocks rest unconformably on the Permian Park City formation. From the base upward the Triassic rocks are (1) red Woodside shale, (2) marine Thaynes limestone, (3) Ankareh redbeds and (4) a conglomerate and overlying sandstones and shales. The Thaynes thins and tongues out eastward, and east of its edge the Woodside and the Ankareh can not be differentiated. The conglomerate, sandstones, and shales were classed as basal Nugget sandstone, Jurassic, by Boutwell (1912), but were excluded from the Nugget (Navajo sandstone) by Heaton (1939), leaving them without a name.

At the eastern end of the mountains, Woodside redbeds rest on the Pennsylvanian Weber sandstone. The lower part of the Woodside is the time equivalent of the upper Park City (Phosphoria). The Woodside is cut by an unconformity above which lies a conglomerate. The conglomerate was questionably classed as the basal member of the Ankareh by Sears (1926). The upper part of the Ankareh (?) of Sears consists of varicolored shales and sandstones and is directly overlain by the massive Navajo sandstone.

The conglomerate and the overlying varicolored beds are readily recognized from one end of the range to the other and constitute an unnamed lithologic unit which lies unconformably above the type Ankareh and below the restricted Nugget at the western end of the mountains, and unconformably above the Woodside and below the Navajo at the eastern end of the range. This unit is here named the Stanaker formation and the basal conglomerate, or grit, is named the Gartra grit member of the Stanaker formation. They are probably Upper Triassic in age.

The Jurassic formations of the western Uinta Mountains, from base upward are (1) Nugget sandstone, (2) Twin Creek limestone, (3) Preuss redbeds, (4) Stump sandstone, and (5) Morrison formation. Eastward along the mountains (1) the Nugget sandstone persists but is called Navajo on the east, (2) the Twin Creek limestone intertongues with the Carmel redbeds, (3) the Preuss redbeds grade into the cross-bedded Entrada sandstone, (4) the Stump sandstone grades into Curtis shales and limestones, and (5) the Morrison thins and becomes less conglomeratic. At the eastern end of the Uinta Mountains the Carmel redbeds thin out so that the Navajo is directly overlain by the Entrada, forming a single cross-bedded sandstone unit.

INTRODUCTION

Along the Uinta Mountains of northeastern Utah and northwestern Colorado there are striking east-west changes in the stratigraphy of the late Paleozoic and Mesozoic rocks. Because the range trends roughly at right angles to the ancient

[1] Manuscript received, March 31, 1946. Read in part before the Association at Denver, April 24, 1942. After the completion of this paper there came to the writers' attention an article entitled "Nomenclature of the Triassic Rocks of Northern Utah," by J. Stewart Williams, which appeared in the *American Journal of Science*, Vol. 234, No. 9 (September, 1945). The stratigraphic relations described in the three-page article by Williams are in close agreement with those herein described. The writers wish to note that they first described the relations of the Triassic rocks along the Uinta Mountains in a paper read at the twenty-seventh annual meeting of the American Association of Petroleum Geologists, Denver, April, 1942, and that an abstract was published in the program (pp. 38–39). In addition, early in 1942, a report prepared by Krueger for the Union Oil Company of California was placed in the office of the Indian Commissioner, Fort Duchesne, Utah. This report has been subject to public inspection. Williams refers to the use of the name "Ankareh grit" in unpublished reports. The report by Krueger used that terminology.

It is not the writers' intent to discuss the nomenclature proposed by Williams except to express their belief that the units they here name Stanaker formation and Gartra grit member are worthy of distinctive local names. The name, Red Wash, given by Williams, may be substituted for Woodside where the writers have used that name in sections in which the Thaynes limestone is not present.

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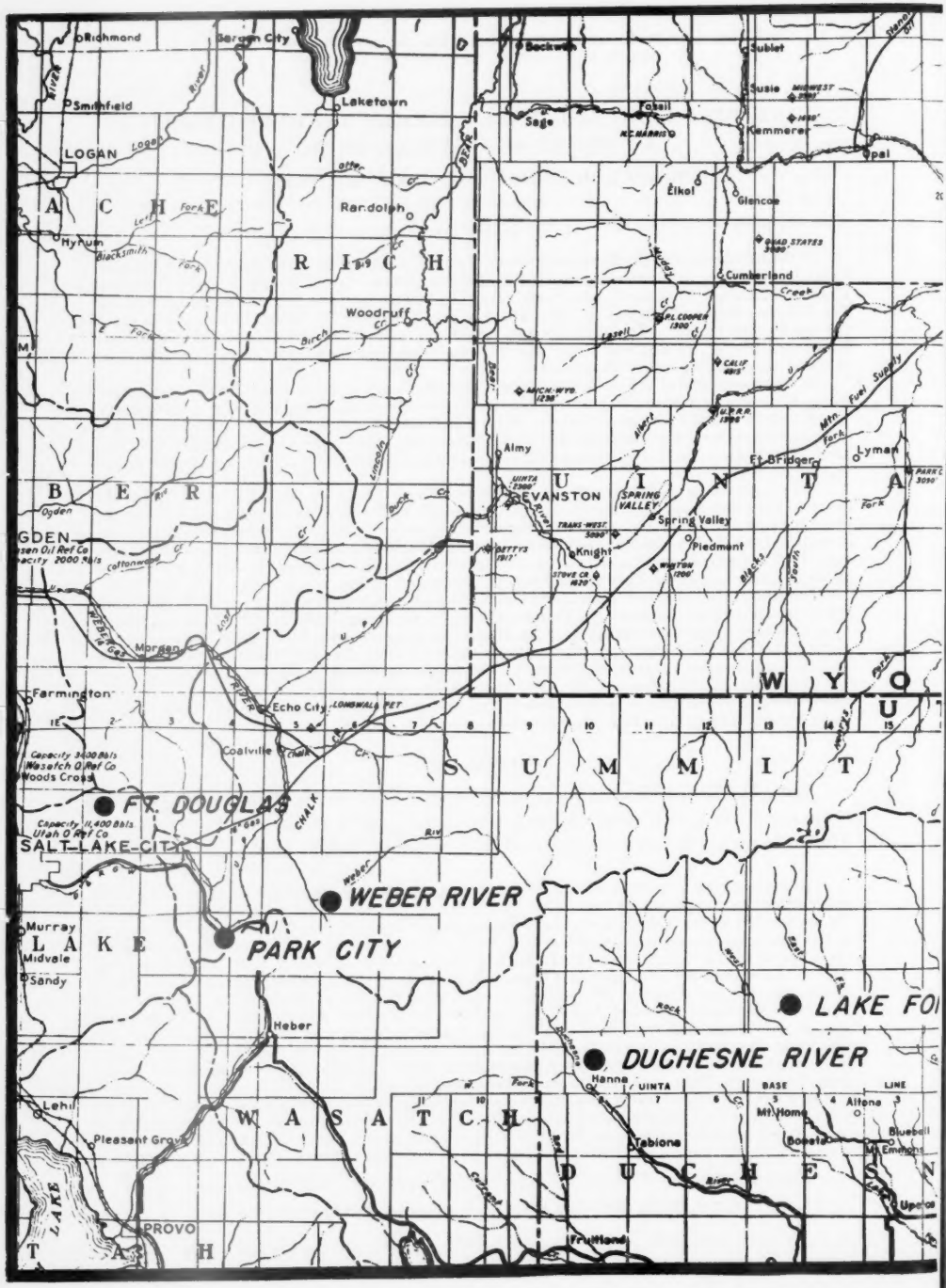
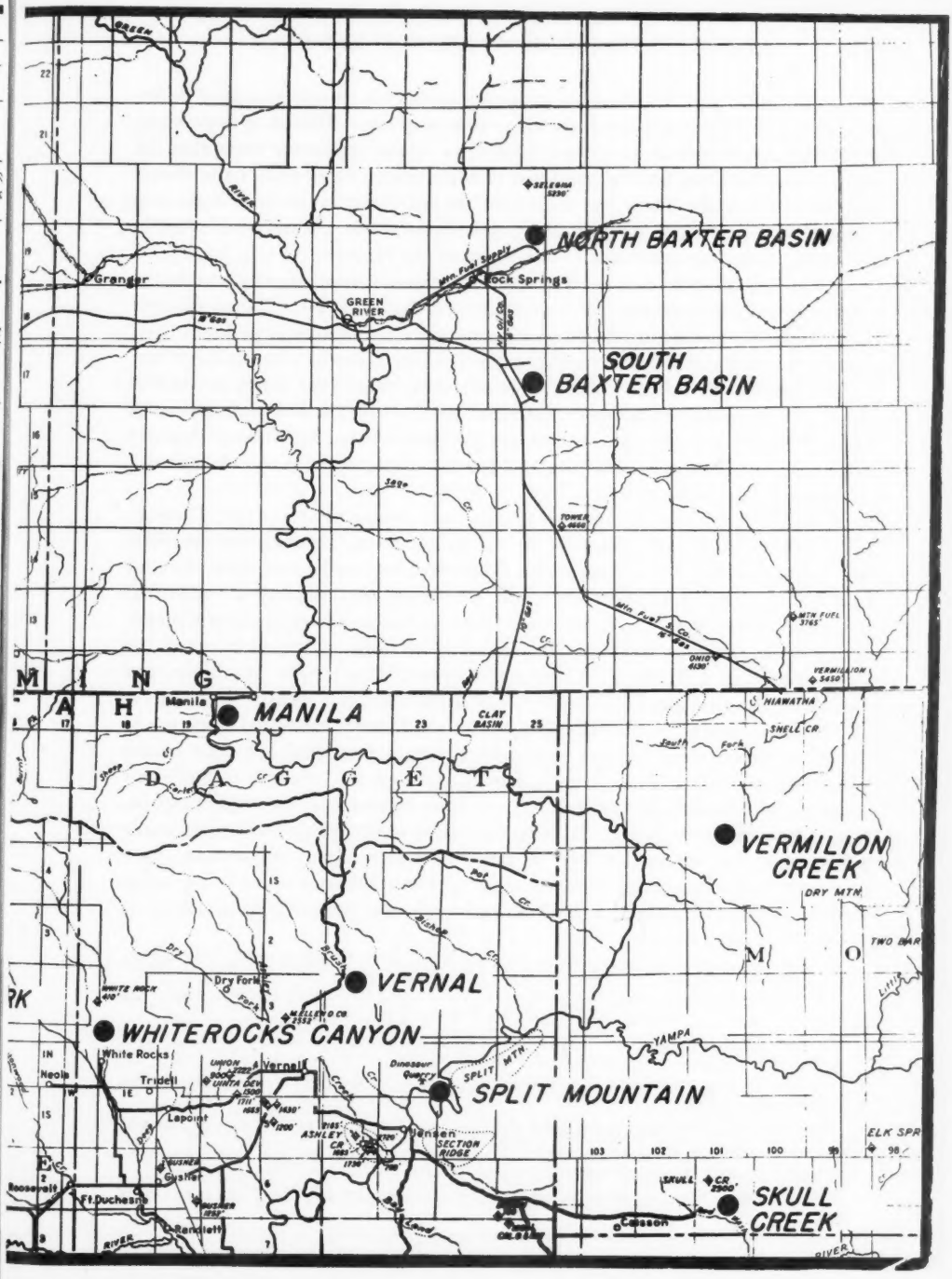


FIG. 1.—Index map showing



localities mentioned in text.

landmasses and shorelines, there are lithologic gradations, interfingerings of facies, and changes in thickness which make long-range correlation difficult or impossible.

Stratigraphic studies have been carried on in the region for more than 70 years, but oddly were largely restricted to the areas at either end of the mountains. Until recently, little was known of the stratigraphy of the intervening region or of the relations of the stratigraphic units which had been described in the strikingly different sections at either end of the range.

In 1918, Schultz[4] studied the Permian rocks from one end of the range to the other, and in 1939 J. Stewart Williams[5] clarified the east-west relations of these rocks along the mountains. In 1939, Heaton[6] gave the first clear picture of the relations of the Jurassic formations at one end of the range to those at the other.

The stratigraphy of the Jurassic Morrison formation of the Uinta Mountains and of contiguous areas has been described by Stokes.[7] The Cretaceous stratigraphy of the south flank of the mountains has been treated by Walton.[8] A paper by Eardley[9] describes the structure and general stratigraphy of the western end of the Uinta Mountains.

During 2 months of the summer of 1939, one writer of this paper, Thomas, had the opportunity to measure or examine all the strategic stratigraphic sections exposed around the Uinta Mountains. This work was under the supervision of Earl B. Noble, manager of exploration of the Union Oil Company of California, and of the co-writer, Krueger. Additional field studies were carried on by Krueger during 1940. Thomas measured stratigraphic sections in the vicinity of the Duchesne River, Lake Fork, Whiterocks Canyon, Vernal, Split Mountain, and Manila. The Vermilion Creek section was studied but not measured. These localities are indicated on the index map (Fig. 1). Krueger measured a section in the Skull Creek area, and the two writers jointly measured a section in the Weber Canyon area. These locality names are used to designate the different sections, even though parts of the sections were measured at a considerable distance from the places named. The exact locations of the sections are given in the headings of the written sections at the end of this paper. All sections were measured with plane table and telescopic alidade. Thicknesses of minor units were measured directly with a tape, a hand level, or a Brunton clinometer set at the angle of dip.

The writers wish to express appreciation to Earl B. Noble, manager of explo-

[4] A. R. Schultz, "A Geologic Reconnaissance of the Uinta Mountains, Northern Utah, with Special Reference to Phosphate," *U. S. Geol. Survey Bull. 690-C* (1918).

[5] J. Stewart Williams, " 'Park City' Beds on Southwest Flank of Uinta Mountains, Utah," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23, No. 1 (1939), pp. 82–100.

[6] Ross L. Heaton, "Contribution to Jurassic Stratigraphy of Rocky Mountain Region," *ibid.*, Vol. 23, No. 8 (1939), pp. 1153–77.

[7] W. L. Stokes, "Morrison and Related Deposits in and Adjacent to the Colorado Plateau," *Bull. Geol. Soc. America*, Vol. 55 (1944), pp. 951–92.

[8] Paul T. Walton, "Geology of the Cretaceous of the Uinta Basin, Utah," *ibid.*, pp. 91–130.

[9] A. J. Eardley, "Geology of the North-Central Wasatch Mountains, Utah," *ibid.*, pp. 819–94.

ration, and to the Union Oil Company of California for permission to publish this paper. James W. Vernon, a promising student in geology at the University of Wyoming who was killed in a fall from a cliff during the course of geological work later in 1939, served as instrument men for the stratigraphic measurements. Other geologists, all then of the Union Oil Company, who contributed to this work through field observations and by discussions are E. R. Atwill, R. W. Burns, J. C. Hazzard, C. F. Manlove, J. Q. Anderson, and W. C. Rauch. Their assistance is appreciated. In addition, the writers are indebted to J. B. Reeside, Jr., A. A. Baker, and J. D. Love of the United States Geological Survey for reading the manuscript and for offering comments and suggestions.

Over large areas along both flanks of the Uintas, the Paleozoic and Mesozoic rocks are covered by Tertiary beds. Younger glacial or fluviatile deposits constitute a mantle at many places. Well exposed sections, therefore, are found only at intervals along the range. The general regional geology is shown on an older map by Schultz[10] and on more recent maps by Forrester[11] and Walton.[12]

The relations of the Triassic rocks along the mountains are here presented for the first time and this paper, therefore, describes the stratigraphy of the interval between the Permian rocks below, described by Williams, and the Jurassic rocks above, described by Heaton. In addition, new information is given on Permian and Jurassic stratigraphy.

EVOLUTION OF STRATIGRAPHIC NOMENCLATURE

WESTERN UINTA MOUNTAINS

The details of the stratigraphy of the Park City district, at the western end of the Uinta Mountains, were first described by Boutwell in 1907[13] (Fig. 2). The name, Weber, applied by King[14] in 1876 to a thick sandstone along the Weber River, north of the Park City district, was carried south by Boutwell and applied to the oldest unit exposed in the Park City district. The Weber is classed as Pennsylvanian in age and has been described recently by Williams.[15] To limestones and other beds lying directly above the Weber, Boutwell applied the new name, Park City. The Park City is classed as Permian in age and the upper part is correlated with the Phosphoria formation.[16] The name, Woodside, was given

[10] A. R. Schultz, *op. cit.*

[11] J. D. Forrester, "Structure of the Uinta Mountains," *Bull. Geol. Soc. America*, Vol. 48, No. 5 (1937), Pl. 3.

[12] Paul T. Walton, *op. cit.*, Pl. 2.

[13] J. M. Boutwell, "Stratigraphy and Structure of the Park City Mining District, Utah," *Jour. Geol.*, Vol. 15 (1907), pp. 434–58.

[14] Clarence King, "Paleozoic Subdivisions on the Fortieth Parallel," *Amer. Jour. Sci.*, 3d Ser., Vol. 11 (1876), pp. 477–79.

[15] J. Stewart Williams, "Carboniferous Formations of the Uinta and Northern Wasatch Mountains, Utah," *Bull. Geol. Soc. America*, Vol. 54, No. 4 (1943), pp. 591–624.

[16] A. A. Baker and J. Steele Williams, "Permian in Parts of Rocky Mountain and Colorado Plateau Regions," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, No. 4 (1940), pp. 716–35.

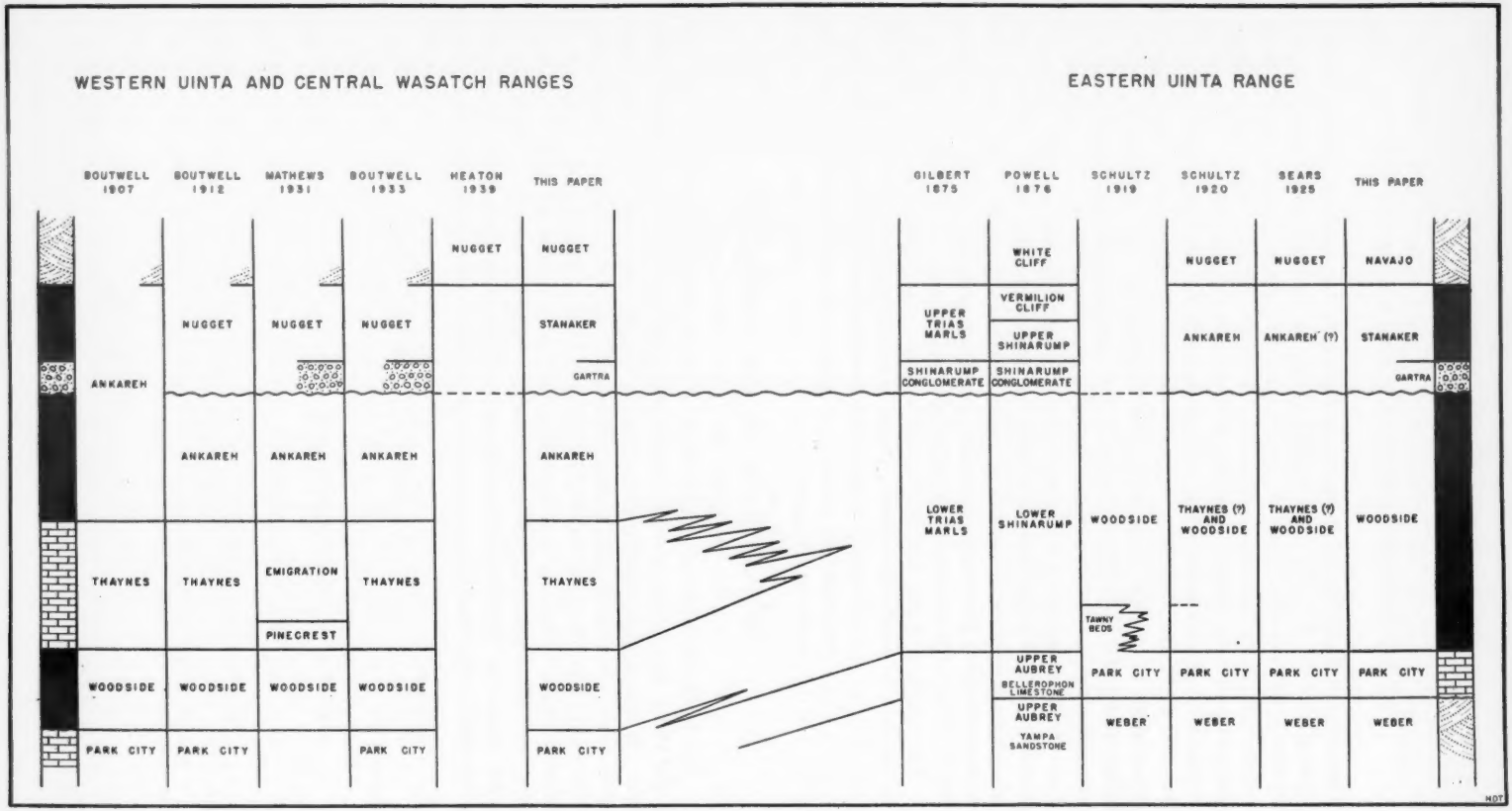


FIG. 2.—Evolution of stratigraphic nomenclature of late Paleozoic and early Mesozoic rocks of Uinta Mountains.

by Boutwell to 700 feet of "fine-grained dark-red shale" overlying the Park City. The next higher formation was named Thaynes limestone by Boutwell. He described the Thaynes as consisting of a lower 445-foot unit made up of fossiliferous limestones, calcareous and other sandstones, and red and gray shale; a middle 115-foot red shale unit; and an upper 630-foot unit lithologically similar to the basal unit. He pointed out that no unconformity was observed below or above the Thaynes. The highest beds exposed in the district were included in the Ankareh formation, named by Boutwell. As described, the Ankareh consisted of more than 1,500 feet of red shales, which in places are sandy, with a number of beds of rather coarse sandstone from 20 to 55 feet thick.

The division between the Thaynes and the Ankareh was based on lithology, the Thaynes being characterized by calcareous beds and the Ankareh by red shales and sandstones. A sandstone lying "at the base of the red shale as a whole and immediately below a thin limestone" was taken arbitrarily as the base of the Ankareh, and typical Thaynes fossils were reported from the basal 200 feet of the Ankareh. Boutwell mentioned a main sandstone member at the top of the Ankareh and the occurrence of petrified wood just below it. The Woodside, Thaynes, and lower Ankareh were classed as Permian; the age of the upper Ankareh was left open to question.

In 1912, Boutwell[17] further described the stratigraphy of the Park City district. Few changes were made other than age assignments. The Woodside, Thaynes, and lower Ankareh were classed as Lower Triassic and the age of the upper Ankareh was again left open to question. The major change made was to bring the name, Nugget, into the region, that name having been applied by Veatch, in 1907, to a sandstone in southwestern Wyoming.[18] The original Nugget of Veatch comprised a lower redbeds part, just above the Thaynes, and an upper thick sandstone part. In 1910,[19] the name, Nugget, had been restricted to the sandstone unit, and Boutwell pointed out that at the top of his original Ankareh were white sandstones with some intercalated reddish shales which he thought represented the lower part of the restricted Nugget.

In 1931, Mathews[20] described the Mesozoic rocks of the Wasatch Mountains in the area northwest of the Park City district. The Thaynes was divided into the Pinecrest formation, below, and the Emigration formation, above. The overlying Ankareh, according to Mathews, is unlike the type Ankareh in that instead of being mainly siliceous sandstone, it is an ox-blood red fine-grained shale with

[17] J. M. Boutwell, "Geology and Ore Deposits of the Park City District, Utah," *U. S. Geol. Survey Prof. Paper 77* (1912).

[18] A. C. Veatch, "Geology and Geography of a Portion of Southwestern Wyoming, with Special Reference to Coal and Oil," *U. S. Geol. Survey Prof. Paper 56* (1907).

[19] H. S. Gale and R. W. Richards, "Preliminary Report on the Phosphate Deposits in Southeastern Idaho and Adjacent Parts of Wyoming and Utah," *U. S. Geol. Survey Bull. 430* (1910), pp. 457–535.

[20] A. A. L. Mathews, "Mesozoic Stratigraphy of the Central Wasatch Mountains," *Oberlin College Lab. Bull.*, New Ser., No. 1 (1931).

only thin beds of sandstone. It was implied that the thickness is 450 feet. The Nugget, as differentiated by Mathews, comprised a basal conglomerate, fine- and coarse-grained sandstones, intercalated gypsiferous dark red to pale blue shales and some limestones, and a characteristic creamy white or yellowish white sandstone at the top of the formation. The basal conglomerate, 48 feet thick in one place, rests above an unconformity.

In 1933, Boutwell[21] further described these formations. In the Park City district he recognized Woodside redbeds at the base; Thaynes limestone; Ankareh bright red shale and sandstone and a few thin limestones; and Nugget, described as a "massive coarse-grained grayish-white cross-bedded sandstone carrying no fauna but some petrified wood." He described the Nugget of the Cottonwood district as a "gray sandstone with a basal conglomerate overlying the Ankareh, together with associated red shale members."[22]

In 1939, Heaton[23] substituted the name Navajo for Nugget and placed the base of the Navajo of the western Uinta Mountains at the base of the massive sandstone unit, excluding the subjacent redbeds and conglomerate. It becomes apparent, therefore, that both Boutwell's and Mathews' concept of the sequence was as follows.

Nugget	Thick sandstone unit
	Redbeds with petrified wood
	Basal conglomerate
Unconformity	
Ankareh	Redbeds
Thaynes	Limestones *et cetera*
Woodside	Redbeds
Park City	Limestones *et cetera*

The important point made here is that both considered the conglomerate and the redbeds with petrified wood to be basal units of the Nugget. As shown later, these two units constitute the so-called Ankareh at the eastern end of the mountains.

EASTERN UINTA MOUNTAINS

As early as 1875, Gilbert[24] divided the redbeds of the eastern Uinta Mountains into (1) †Lower Trias marls at the base, (2) Shinarump conglomerate, and (3) †Upper Trias marls above.*

In 1876, Powell[25] described the stratigraphic sequence along the Green River.

[21] J. M. Boutwell, "The Salt Lake Region," *Sixteenth Internat. Geol. Cong., U. S., Guidebook 17* (1933), pp. 73–74.

[22] *Ibid.*, p. 86.

[23] Ross L. Heaton, *op. cit.*

[24] G. K. Gilbert, "Report on the Geology of Portions of Nevada, Utah, California and Arizona," *U. S. Geol. and Geog. Survey W. 100th Meridian* (Wheeler), Vol. 3 (1875), pp. 17–187.

* Stratigraphic names which have been abandoned or have become obsolete are indicated by a dagger preceding the term.

[25] J. W. Powell, "Geology of the Eastern Portion of the Uinta Mountains," *U. S. Geol. and Geog. Survey Terr.* (Powell) (1876).

A thick sandstone, the Weber of current nomenclature, was named the †Yampa sandstone. The overlying unit of phosphatic shale, limestone and chert, now recognized as Park City, was called the †Bellerophon limestone. The redbeds next above were called †Shinarump group and divided into †Lower Shinarump, Shinarump conglomerate, and †Upper Shinarump. Powell said, "The conglomerate which is found in the middle of the group is persistent over a very large area . . ." (p. 69) and "The variegated beds above . . . the conglomerate are seen in many places on either flank of the Uinta Mountains . . . " (p. 54).

Powell differentiated certain beds above the †Shinarump group as the †Vermilion Cliff group but it is difficult to determine the boundary in the field to-day. He gave the name †White Cliff group to the light-colored cross-bedded sandstone above the †Vermilion Cliff group. This is the Navajo or Nugget sandstone of current nomenclature.

In 1919, Schultz,[26] studying the phosphate deposits, applied the name, Weber, to Powell's †Yampa sandstone and carried the term, Park City formation, into the eastern Uinta Mountains. In places he included tawny beds in the top of the Park City, but there are no such beds in the upper part of the type Park City. The redbeds just above were classed as Woodside formation.

Later, in 1920, Schultz,[27] on a chart, classed the main body of redbeds above the Park City as "Woodside and Thaynes (?)." An unconformity was shown above this unit and the name, Ankareh, was applied to the 300 feet of beds between the unconformity and the Nugget sandstone.

In 1925, Sears[28] gave a detailed section measured on Vermilion Creek. The nomenclature of Schultz, 1920, was used except for questioning the name, Ankareh. The "Ankareh (?)" of Sears comprised a basal conglomerate and overlying varicolored beds.

Workers in the eastern Uinta Mountains, therefore, have applied the name, Ankareh, to a conglomerate and varicolored beds which can be shown to lie above the type Ankareh and were included in the Nugget sandstone by workers in the western Uinta Mountains. The conglomerate and overlying varicolored beds constitute important units in the stratigraphy of the Uinta Mountains and have never been properly named.

PERMIAN STRATIGRAPHY

Park City formation.—The Park City formation of the Uinta Mountains, originally described by Boutwell,[29] has been discussed recently by A. A. Baker

[26] A. R. Schultz, *op. cit.*

[27] A. R. Schultz, "Oil Possibilities in and around Baxter Basin, in the Rock Springs Uplift, Sweetwater County, Wyoming," *U. S. Geol. Survey Bull. 702* (1920), p. 36.

[28] J. D. Sears, "Geology and Oil and Gas Prospects of Part of Moffat County, Colorado, and Southern Sweetwater County, Wyoming," *U. S. Geol. Survey Bull. 751-G* (1924), pp. 280–81.

[29] J. M. Boutwell, "Stratigraphy and Structure of the Park City Mining District, Utah," *Jour. Geol.*, Vol. 15 (1907), pp. 439–58.

and J. Steele Williams,[30] and by J. Stewart Williams.[31,32] Baker and Williams discussed the relation of the type Park City to the type Phosphoria of Idaho and showed that the upper cherty limestone unit and the subjacent phosphatic shale unit of the type Park City correspond with the Phosphoria. Even though the phosphatic shale unit of the Park City rests directly on the Weber sandstone in places along the Uinta Range (Fig. 3) and the beds there could conceivably be called Phosphoria formation, the writers have preferred to use the name, Park City, throughout the area since in few places do the beds of Phosphoria lithology have the exact time scope of the type Phosphoria.

J. Stewart Williams[33] described the interfingering of the Park City with redbeds along the south flank of the mountains. The writers remeasured or examined all

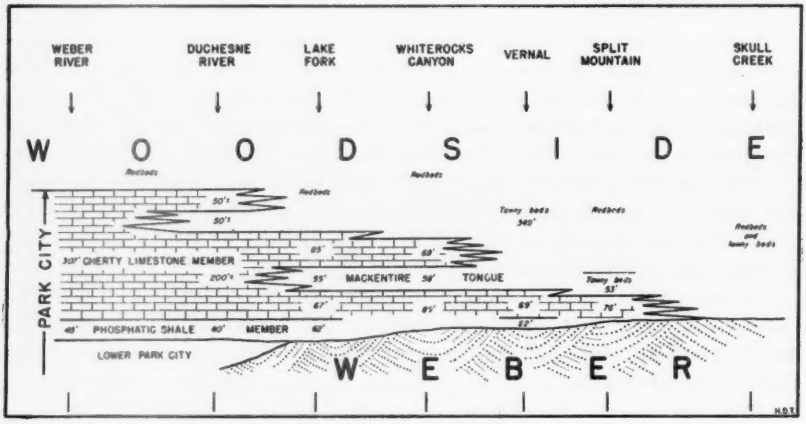


FIG. 3.—Diagram illustrating relations of Park City and Woodside formations along south flank of Uinta Mountains.

the sections described by Williams and measured additional ones farther east. The details of the interfingering are given a slightly different interpretation from those illustrated by Williams.

On the Weber River, at the western end of the mountains, in Franson Canyon, the Park City has a typical tripartite division. The upper cherty member is 307 feet thick and overlies the phosphatic shale member, which is 45 feet thick. The

[30] A. A. Baker and J. Steele Williams, *op. cit.*, pp. 627–29.

[31] J. Stewart Williams, " 'Park City' beds on Southwest Flank of Uinta Mountains, Utah," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23, No. 1 (1939), pp. 82–100.

[32] ———, "Carboniferous Formations of the Uinta, and Northern Wasatch Mountains, Utah," *Bull. Geol. Soc. America*, Vol. 54, No. 4 (1943), pp. 617–19.

[33] J. Stewart Williams, " 'Park City' Beds on Southwest Flank of Uinta Mountains, Utah," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23, No. 1 (1939), pp. 82–100.

part of the Park City below the phosphatic shale was not studied in detail, but lithologically it is similar to parts of the Phosphoria of Idaho and Wyoming, and the few fossils collected, comprising *Schizodus* sp., *Orbiculoidea utahensis*, and shark denticles like those in the Phosphoria of central Wyoming, suggest a close relation to the part of the formation above the phosphatic shale.

The phosphatic shale persists as a unit eastward from Franson Canyon along the south flank of the mountains. In the central part it rests directly on the Weber sandstone and the lower Park City is missing. Near Vernal, the eastern-

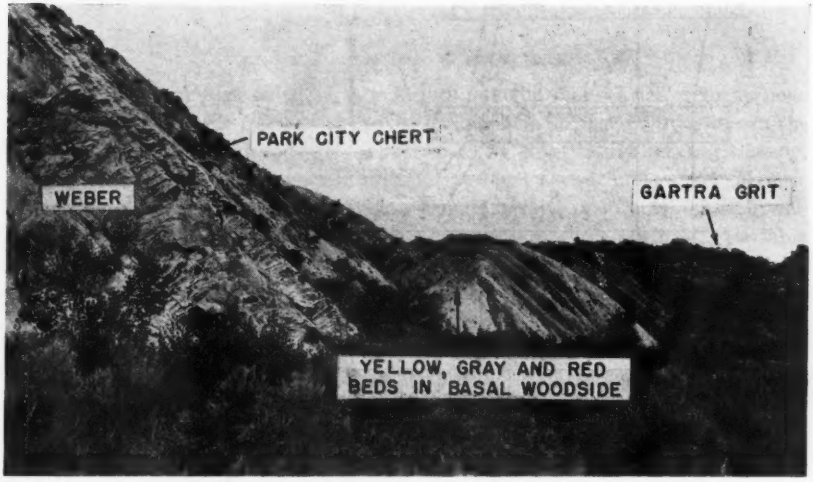


FIG. 4.—Thin Park City chert resting on Weber sandstone at Split Mountain. Yellow, gray and red beds in the basal Woodside are Park City in age.

most section in which phosphatic shale was seen, it is 22 feet thick, but at Split Mountain the member could not be recognized and the basal Park City there has assumed a cherty nature (Fig. 4).

The upper Park City cherty member, east of Franson Canyon, is penetrated from the east by tongues of redbeds which are evident in sections along the Duchesene River, Lake Fork, and at Whiterocks Canyon. The cherty member is partly replaced by redbeds at Lake Fork, but a cherty limestone tongue extends eastward and forms the upper unit of the Park City at Lake Fork and at Whiterocks Canyon. This unit is completely replaced by redbeds between Whiterocks Canyon and the next exposures eastward, near Vernal. A red shale tongue, named the Mackentire tongue by Williams,[34] is recognizable in the Lake Fork and Whiterocks Canyon sections, but east of the edge of the overlying cherty

[34] *Ibid.*, pp. 91–92.

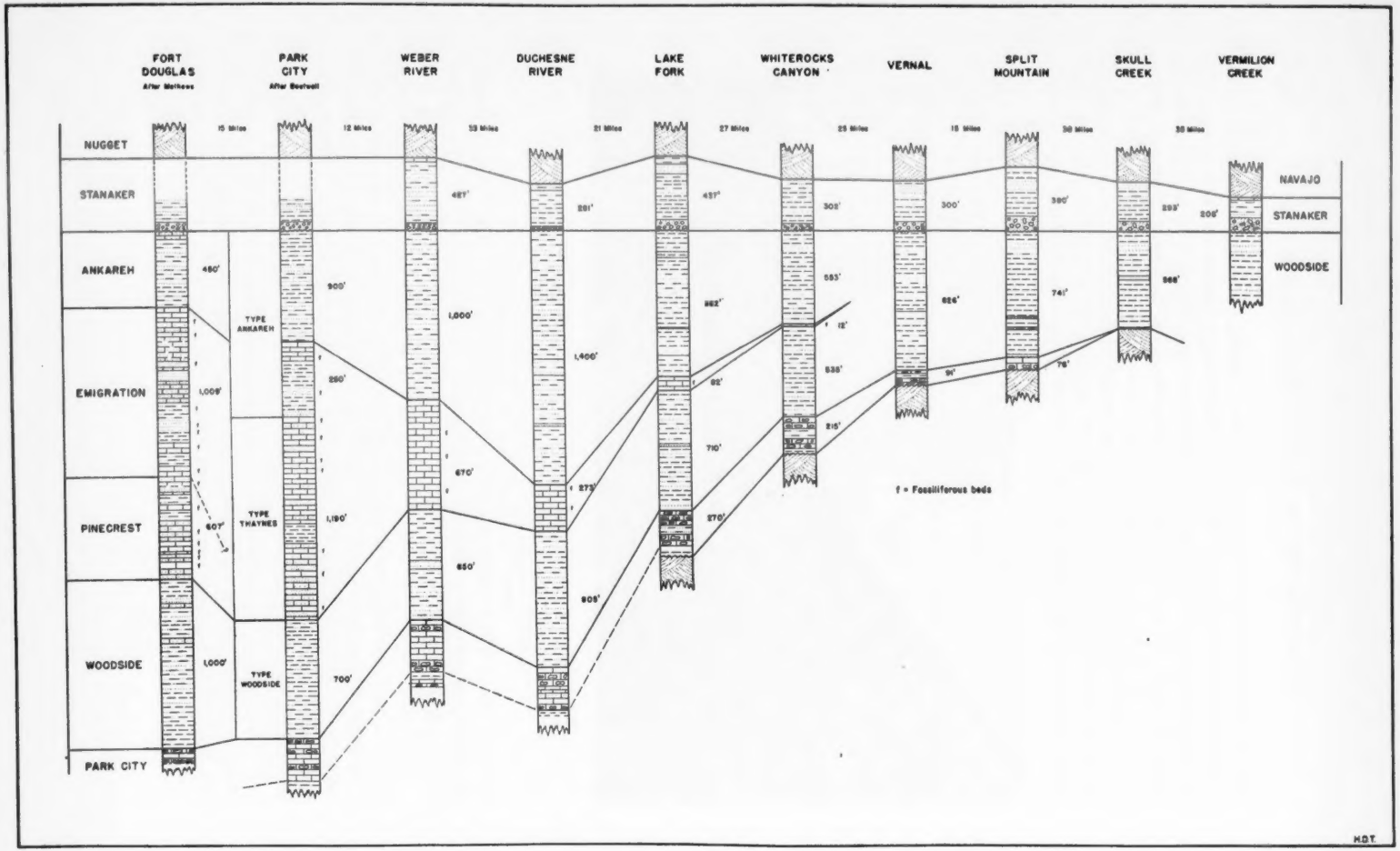


FIG. 5.—Correlation of Triassic rocks along south flank of Uinta Mountains.

tongue, as near Vernal, can not be separated from the Woodside. The basal part of the upper Park City cherty member extends eastward as far as Split Mouhtain, but at Skull Creek, the easternmost section studied, has been replaced by red or tawny shale. At Skull Creek, the basal part of the Woodside is the time-equivalent of the upper Park City cherty member of sections on the west. This interfingering with and replacement by redbeds is similar to that in Wyoming where the Phosphoria of sections in central Wyoming is represented in the basal Chugwater redbeds in southeastern Wyoming.[35]

TRIASSIC STRATIGRAPHY

GENERAL RELATIONS OF FORMATIONS

In the western part of the Uinta Mountains the older Triassic formations comprise the Woodside redbeds at the base, the marine Thaynes limestone in the middle, and the Ankareh redbeds, as restricted by Boutwell (Fig. 5) at the top. The restricted Ankareh is overlain unconformably by a set of younger Triassic beds which comprise a conspicuous basal conglomerate, or grit, which Boutwell considered to be the basal unit of the Nugget sandstone, and an overlying variable sequence of lavender, red, maroon, ocher and green shales, reddish and tannish sandstones, silty sandstones, and sandy siltstones, with less common limestones or calcareous shales. These varicolored beds are overlain by the thick distinctive Nugget (Navajo) sandstone.

To the eastward, the major changes in the older Triassic formations are (1) a general thinning, and (2) the wedging-out of the Thaynes limestone. The wedging-out of the Thaynes brings the lower redbeds (Woodside) into contact with the upper redbeds (Ankareh) and there is no apparent demarcation between rocks representing the two units.

The grit and overlying varicolored beds which unconformably overlie the type Ankareh along the western part of the mountains persist eastward with but little change and are conspicuous at the eastern end of the range, where they have been called Ankareh (?) formation. These beds are here given the name Stanaker formation, and the basal conglomerate designated as the Gartra grit member. Their stratigraphic details are discussed fully later in this paper.

EARLIER TRIASSIC STRATIGRAPHY

Nomenclatural problems.—It is unfortunate, perhaps, that Boutwell divided the older Triassic rocks into three formations, since away from the type locality the lower redbeds (Woodside) can be separated from the upper redbeds (Ankareh) only where the Thaynes limestone is present. East of the wedge-edge of the Thaynes, the single redbeds unit might be referred to as "Woodside-Ankareh," but the use of such hypenated names is not in accord with the best principles of

[35] Horace D. Thomas, "Phosphoria and Dinwoody Tongues in lower Chugwater of Central and Southeastern Wyoming," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 18, No. 12 (1934), pp. 1655–97.

FIG. 5.—Correlation of Triassic rocks along south flank of Uinta Mountains.

stratigraphic nomenclature. It would be best to apply a group name to include Woodside, Thaynes, and Ankareh which could be used as a formation name where the Thaynes limestone is absent. This would involve the application of a new name which would have to be substituted for the name, Woodside, as it is now used in many places. Such a revision made now might not be entirely workable later. For instance, the Woodside thins strikingly between Vernal and Skull Creek (Fig. 5) and this thinning is known to continue southward and southeastward. In the thin sections the Woodside is probably equivalent only to type Woodside, with no Ankareh equivalent present. The writers prefer to postpone any revision of the nomenclature until the time when additional detailed information is available on the stratigraphy of the older Triassic rocks over a greater area than that considered in this paper and until regional relationships are better understood. Until that time it seems best in the Uinta Mountains region to use the names, Woodside, Thaynes, and Ankareh, in a formational sense over the area where all three are present, and to use the name, Woodside, as has been done, over the area in which the Thaynes is lacking, taking recognition of the fact that in some places beds as young as Ankareh may be included in the upper part of the Woodside.

Woodside shale.—Along the western part of the Uinta Mountains, the Woodside consists of 500 to 800 feet of red to maroon shales, siltstones, and very fine-grained sandstones, the monotony of color being broken rarely by thin gray or greenish siltstones or sandstones. Along the eastern part of the mountains, however, the red color of the formation gives way to considerable thicknesses of tawny, tan, or olive-drab beds. No traces of fossils were found in any part of the Woodside on the south flank of the Mountains.

In western Wyoming the Phosphoria is overlain disconformably by the Dinwoody formation, which has been dated by Newell and Kummel[36] as early Lower Triassic in age. The type Woodside rests directly above the Phosphoria equivalent of the Park City, and it is likely that the lower Woodside is a redbeds facies of the same age as the Dinwoody. Eastward, along the Uinta Mountains, however, it is impossible to separate redbeds of Park City age from the true Woodside, and the base of the Woodside descends in the section until at Skull Creek the entire upper Park City is represented by the basal Woodside. The red Chugwater and Spearfish shales of eastern Wyoming are similarly made up of Permian and Triassic parts which can not be separated at the present time.

Near Vernal the lower part of the Woodside is characterized by tawny beds which rest on the thin basal chert of the Park City and are 350 feet thick. They were classed as the upper part of the Park City by Schultz,[37] although he pointed out their similarity to the Dinwoody formation of Wyoming. The tawny beds

[36] Norman D. Newell and Bernhard Kummel, "Lower Eo-Triassic Stratigraphy of Western Wyoming and Southeast Idaho," *Bull. Geol. Soc. America*, Vol. 53 (1942), pp. 937–96.

[37] A. R. Schultz, "A Geological Reconnaissance of the Uinta Mountains, Northern Utah, with Special Reference to Phosphate," *U. S. Geol. Survey Bull. 690-C* (1918), p. 54.

near Vernal, however, differ from the type Dinwoody in that the lower part is Permian in age. At Manila, on the north flank of the Uinta Mountains, the Park City is overlain by 740 feet of tawny beds, and the entire Woodside at Vermilion Creek, at the eastern end of the mountains, has a tawny color.[38] Gilluly has shown that the Moenkopi of the San Raphael Swell, whose lower part is the probable equivalent of the Woodside, varies from redbeds to tawny beds, that there is a gradation between the two lithologic types, and that the tawny beds were probably deposited in a somewhat different environment from the redbeds.[39]

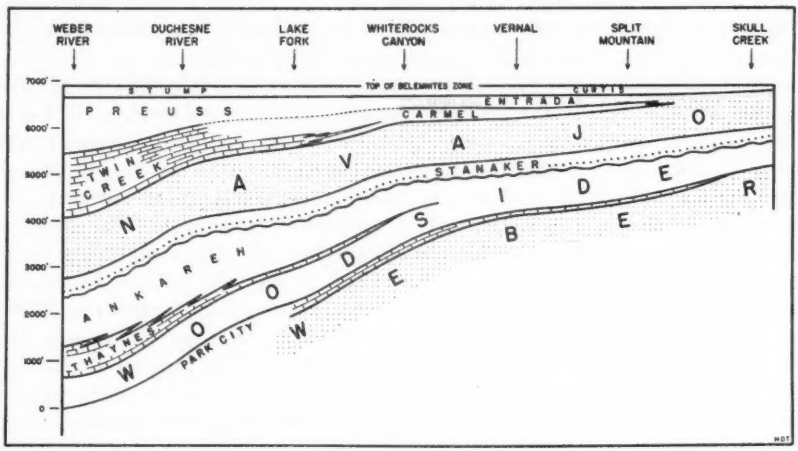


FIG. 6.—Stratigraphic diagram showing relations of Permian, Triassic, and Jurassic formations along south flank of Uinta Mountains.

Although tawny beds are conspicuous in the eastern part of the Uinta Mountains they do not constitute a definite unit. They are partly Park City in age and partly Woodside in age and should be included with the Woodside rather than described as a distinct stratigraphic unit.

The eastward thinning of the Woodside in the area where it is overlain by Thaynes limestone is probably attributable to more rapid sedimentation on the west than on the east during the same span of geologic time. The thinning of the Woodside and Ankareh, where the two units are not separated by Thaynes limestone, as in the area between Vernal and Skull Creek, is apparently related to the unconformity at the base of the Gartra grit. It is suggested that the Woodside at Skull Creek probably represents rocks nearly equivalent to the type Woodside,

[38] J. D. Sears, *op. cit.*, p. 281.

[39] James Gilluly, "Geology and Oil and Gas Prospects of Part of the San Raphael Swell, Utah," *U. S. Geol. Survey Bull. 806-C* (1929), p. 86.

and that beds of post-Woodside age were largely removed by erosion prior to the deposition of the Gartra grit (Fig. 6).

Thaynes limestone.—The Thaynes limestone at the western end of the mountains is made up of gray to brown thick-bedded to thin-bedded limestones, sandy limestones, and calcareous sandstones. Certain parts are very fossiliferous, but no attempt was made by the writers to obtain complete faunal collections for study. The Thaynes is, however, obviously a normal marine deposit. As the Thaynes thins eastward it becomes a white very fine-grained sandy limestone in beds ranging from one to two feet in thickness. In the vicinity of Deep Creek, between Whiterocks Canyon and Vernal, the Thaynes has thinned to less than 2 feet, but still contains a few fossils. East of Deep Creek it is not identifiable, although some thin calcareous laminae persist for a short distance.

Ankareh formation.—The Ankareh, like the Woodside, is made up predominantly of red to maroon shales, siltstones and very fine-grained sandstones. There may be intercalated beds of coarser sandstone, either gray or red in color, but these do not form an appreciable part of any section. A thin bed of gypsum was noted in the Ankareh along Lake Fork, but no gypsum was seen elsewhere.

There is some indication that there is a gradation between the Thaynes limestone and the Ankareh, with limestone replaced by redbeds eastward (Fig. 6). It is suggested that the redbeds thicken eastward between Weber River and Duchesne River at the expense of the Thaynes, which thins. The fact that Boutwell reported marine fossils in calcareous beds in the lower part of the sequence he classed as Ankareh,[40] and that the dividing line between Thaynes and Woodside was arbitrarily placed at the point of major lithologic change, lends support to this concept. The eastward thinning of the Ankareh between Duchesne River and Whiterocks Canyon is attributable to erosion and beveling of the Ankareh prior to the deposition of the Gartra grit.

LATER TRIASSIC STRATIGRAPHY

General considerations.—It has been pointed out that the conglomerate and varicolored beds which at the west end of the Uinta Mountains were included by Boutwell in the base of the Nugget and which at the east end of the mountains were called Ankareh (?) by Schultz, constitute important stratigraphic units which are without names. It is the object here to apply new names and to describe the regional stratigraphy of the units.

It would be possible to bring in formation names from elsewhere and apply them to the rocks in question, but if new names are given there is no chance for an error in correlation and, in addition, the names will be distinctive of the Uinta Mountain region.

As frequently happens in selecting names for stratigraphic units in the West, the writers were hard-pressed to find suitable geographic names near best ex-

[40] J. M. Boutwell, "Geology and Ore Deposits of the Park City District, Utah," *U.S. Geol. Survey Prof. Paper 77* (1912), pp. 58–59 and Pl. 5.

posures of the units to be named. Article 7, Remark b, of the "Classification and Nomenclature of Rock Units,"[41] points out that the type section of a stratigraphic unit need not be located exactly at the geographic point from which the name is derived, though it should not be far removed. Because of the scarcity of acceptable geographic names in the area about the type section, the writers have found it necessary to go rather far afield in order to find desirable names.

*Stanaker formation (new name)**—The name, Stanaker formation, is here applied to the basal conglomerate and overlying varicolored shales and sandstones which were included in the Nugget by Boutwell and classed as Ankareh (?) by Sears. To the basal conglomerate the name Gartra grit member of the Stanaker formation (new name) is here applied. The name, Stanaker, is derived from Stanaker Draw which lies in the eastern part of T. 3 S., R. 21 E., Uintah County, Utah, and is shown on the United States Geological Survey topographic sheet of the Marsh Peak Quadrangle.[42] The name, Gartra, is taken from Gartra Spring, located in Sec. 11, T. 2 S., R. 21 E., as shown on the United States Forest Service map of the Ashley National Forest.

The type section of the Stanaker formation and of the Gartra grit member, however, is located at the point where the Vernal-Manila highway crosses Brush Creek, about 10 miles north of Vernal, in the north part of Sec. 5, T. 3 S., R. 22 E. The stratigraphic section, here given as the type section (see p. 1289), was measured immediately south of Brush Creek, where the Gartra grit forms a cliff just south of a ranch a few hundred feet west of the Vernal-Manila highway and where the upper part of the formation is exposed along the highway just south of Brush Creek.

At the type section the Gartra grit rests unconformably on a surface exhibiting considerable relief cut on the Woodside shale (Fig. 7). There is a sharp lithologic change from Woodside redbeds below the erosion surface to gray cross-bedded grit above. A similar relationship is shown in all exposures around the Uinta Mountains. Because of the irregular nature of the basal contact, the Gartra grit ranges in thickness from 40 to 80 feet near the type section.

Everywhere along the south flank of the Uinta Mountains, from Weber River to Skull Creek, and at Vermilion Creek, the Gartra grit is gray poorly sorted coarse-grained feldspathic quartz grit with sporadic quartz pebbles as large as one inch in diameter. In places the coarser grit and pebble beds seem to be lenticular in nature. The poorly sorted character of the grit causes marked changes in texture both laterally and vertically, but in general the bed is coarser in texture near the base than near the top.

[41] G. H. Ashley *et al.*, "Classification and Nomenclature of Rock Units," *Bull. Geol. Soc. America*, Vol. 44 (1933), p. 433.

* The names Stanaker and Gartra have not been used previously in stratigraphic nomenclature and are, therefore, available as new names.—Personal communication, H. D. Miser, United States Geological Survey, May, 1946.

[42] On the United States Forest Service map of the Ashley National Forest, the name is spelled Steinaker, but the older spelling is preferred by the writers.

The upper contact of the grit is sharp and the bed is in most places directly overlain by shale. In places, as in the type section, there are thin grit beds lithologically like the main grit body, but not as coarse-grained, interbedded in the shales just above the Gartra. Whether or not there are thin grit beds above the Gartra grit member in other sections can not be determined because of poor exposures.

Variations in thickness of the Gartra grit are as follows: Weber River, 33 feet; Duchesne River, 26 feet; Lake Fork, 67 feet; Whiterocks Canyon, 43 feet; Split

FIG. 7.—Unconformable relation of Gartra grit and Woodside shale on Brush Creek, north of Vernal, Utah.

Mountain, 93 feet; Skull Creek, 66 feet; and Vermilion Creek, according to Sears, 88 feet.[43]

In one section, directly along the Duchesne River near Hanna, the grit could not be found. It is present on Farm Creek, several miles east of Hanna, and also at the west in the Park City district, on the Weber River, and, according to Mathews,[44] at many places in the Wasatch Mountains. Since the bed presents all the characters of a fluviatile deposit, it would not be unexpected for it to thin out in places; however, it may be covered or faulted out along the Duchesne River.

At Manila, on the north flank of the mountains, the Gartra differs strikingly in lithologic character from the occurrences on the south flank of the mountains.

[43] J. D. Sears, *op. cit.*, p. 280.

[44] A. A. L. Mathews, *op. cit.*, pp. 41–42.

There it consists of lenses of purplish red limestone pebble conglomerate set in a matrix of purplish red cross-bedded coarse-grained sandstone. The bed has a sharp contact with the subjacent Woodside and lithologically is strikingly dissimilar to the underlying red siltstones. The thickness is 18 feet. Higher in the section, however, and separated from the limestone pebble conglomerate by 120 feet of shales, is a 3-foot bed of very coarse-grained quartz granule grit which is lithologically like the grit on the south flank of the mountains.

The part of the Stanaker formation lying above the Gartra grit member is made up of varicolored shales and sandstones which are sharply overlain by the massive Nugget or Navajo sandstone. Lying between two resistant units, these softer beds are generally not well exposed. The main body of the Stanaker formation comprises an alternation of shales which vary in color from maroon to red, pink, lavender, ocher, and green, and of sandstones which are gray, red, purple, or yellow in color. The different colors in any one section seem fairly well confined to certain beds. Limestones are not conspicuous, but in the Weber River section there is a pink and gray platy thin-bedded ribbon limestone near the top of the formation, and some sandstones in other sections are calcareous.

The only fossils found in the formation were fragments of silicified wood. Boutwell mentioned the occurrence of petrified wood in beds he classed with the Nugget sandstone,[45] but which probably represent the Stanaker formation.

The thickness of the upper part of the Stanaker, exclusive of the Gartra grit, is as follows: Weber River, 394 feet; Duchesne River, 255 feet; Lake Fork, 370 feet; Whiterocks Canyon, 259 feet; Brush Creek (type section) 240 feet; Split Mountain, 287 feet; Skull Creek, 227 feet; Manila, 284 feet; and Vermilion Creek, 120 feet, according to Sears.[46]

The feldspathic nature of the Gartra grit implies that it was derived from a granitic terrane. It is quite possible that the source of the grit was the granite of the Uncompahgre positive area of central-western Colorado, about 125 miles southeast of the eastern end of the Uinta Mountains. This uplift was a positive area well into Jurassic time.[47] The limestone pebble conglomerate of the Manila area apparently had a different source, although later some grit was carried that far northward. This limestone pebble conglomerate is lithologically like the Jelm conglomerate which occurs along the Sierra Madre and Medicine Bow Mountains of southeastern Wyoming, east of the Uinta Mountains.

Age and correlation.—The writers have no paleontologic evidence which might determine the age of the Stanaker formation, but on the basis of regional rela-

[45] J. M. Boutwell, "The Salt Lake Region," *Sixteenth Internat. Geol. Cong., U. S., Guidebook 17* (1933), p. 86.

[46] J. D. Sears, *op. cit.*, p. 280.

[47] A. A. Baker, C. H. Dane, and J. B. Reeside, Jr., "Correlation of the Jurassic Formations of Parts of Utah, Arizona, New Mexico and Colorado," *U. S. Geol. Survey Prof. Paper 183* (1936), p. 44, Fig. 15.

tionships it is probably Upper Triassic in age. The Thaynes has generally been classed as Lower Triassic in age.[48] The marine faunas in the lower part of the type Ankareh have not been studied, but Boutwell pointed out that they show general agreement with the Thaynes fauna. The Ankareh, therefore, is probably Lower Triassic in age.

In southern Utah and Arizona and in central and southeastern Wyoming are beds whose age has not been determined to the satisfaction of all, but which are generally classed as Upper Triassic. They are characterized in part by coarse clastic sediments and in places rest unconformably on the older Triassic rocks. These are such units as the Shinarump and Chinle of the Colorado Plateaus, the Jelm of southeastern Wyoming, and the Popo Agie of central Wyoming. The writers believe that the Stanaker is correlative with these formations, and like them should be assigned to the Upper Triassic.

It is of interest to note that early workers, in 1875 and 1876, correlated the conglomerate, here called the Gartra grit, with the Shinarump conglomerate of southern Utah and Arizona. Baker, Dane, and Reeside were the last writers to consider at any length the later Triassic rocks of the Uinta Mountains,[49] and the Stanaker formation, which they called Ankareh (?) at Vermilion Creek, at Dinosaur Quarry (Split Mountain), and at other localities in northwestern Colorado and northeastern Utah, was classed as Upper Triassic and correlated with the Chinle formation.

On the other hand, some geologists have suggested that the beds now called Stanaker may be Jurassic in age, and such a consideration can not be lightly dismissed. Because the writers correlate the Stanker with the Shinarump and the Chinle, and because the Chinle has yielded vertebrates considered to be Triassic types, a Triassic age is favored for the Stanaker. If, however, the paleontologic evidence furnished by the Chinle be overlooked, the physical relations of the Stanaker would favor its being considered as the introductory Jurassic unit. Both Boutwell and Mathews drew the Triassic-Jurassic boundary at the base of the Gartra grit on the basis of physical evidence. Reeside states, in respect to the Stanaker, that "The Ankareh (?) formation of the eastern Uintas . . . is most logically viewed as introductory to the Nugget."[50] In addition, Mathews[51] has reported a single *Trigonia* from the Nugget, and this has been cited by later writers in discussing the Jurassic age of the Navajo or Nugget. It must be recalled that Mathews included the Stanaker as the basal unit of his Nugget, and it is likely that the fossil came from the Stanaker formation, for he says the specimen

[48] M. Grace Wilmarth, "Lexicon of Geologic Names of the United States," *U. S. Geol. Survey Bull. 896* (1938), p. 2135.

[49] A. A. Baker, C. H. Dane, and J. B. Reeside, Jr., *op. cit.*

[50] J. B. Reeside, Jr., "Triassic-Jurassic Red Beds of the Rocky Mountain Region: A Discussion," *Jour. Geol.*, Vol. 37 (1929), pp. 56–57.

[51] A. A. L. Mathews, *op. cit.*, p. 42.

was found in " . . . the sandstones near the base above the conglomerate." The value of a single fossil, about which nothing is known other than the original report, is surely subject to question, however.

In summary it may be said that lithology and stratigraphic position favor a correlation of the Stanaker with the Shinarump and Chinle, whose Upper Triassic age seems well established. Other evidence suggests a possible Jurassic age.

JURASSIC STRATIGRAPHY

Heaton[52] was the first to correlate the Jurassic rocks between southeastern Idaho, the south flank of the Uinta Mountains, and northwestern Colorado. This work filled in the stratigraphy of an area not included by Baker, Dane, and Reeside in their treatise on the Jurassic formations of Utah, Arizona, New Mexico, and Colorado.[53]

The writers had independently reached the same conclusions as Heaton prior to the publication of his work, and are in complete accord with his correlations. Since Heaton gave no lithologic details of the various formations, other than by depicting them on a correlation chart and discussing them in general terms, the writers believe it worthwhile to make available the stratigraphic details. In addition, localities not discussed by Heaton are considered.

Nugget or Navajo sandstone.—As shown on the correlation chart (Fig. 8) and the diagram showing stratigraphic relations (Fig. 6), the Navajo or Nugget sandstone, everywhere along the Uinta Mountains, rests on the Stanaker formation. The contact of the massive cross-bedded Navajo with the older varicolored beds is not commonly exposed. Where visible it is sharp, but there is little physical evidence of an unconformity at that stratigraphic level. The lithology of the Navajo is uniform along the mountains, as given in the measured sections, but the color changes from salmon-pink along the western end of the range to white along the eastern part. On Rock Creek, about 12 miles east of the Duschesne River, the upper part of the Navajo is white and the lower part is salmon-pink. The color change cuts obliquely across the sandstone without regard to bedding. There is a general thinning from west to east, the thickness of the formation ranging from 1,293 feet at Weber River to 780 feet at Split Mountain. The thickness near Manila, on the north flank of the Mountains, is 838 feet.

Twin Creek limestone and Carmel redbeds.—In the western part of the Uinta Range the thick marine Twin Creek limestone overlies the Nugget. Along the Weber River the Twin Creek consists of 1,351 feet of light gray limestone, shaly limestone, and calcareous shale; certain beds containing abundant columnals of *Pentacrinus* and specimens of *Trigonia*, *Camptonectes*, and other invertebrate fossils. Eastward the Twin Creek thins in a short distance, the major thinning taking

[52] Ross L. Heaton, "Contribution to Jurassic Stratigraphy of Rocky Mountain Region," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23, No. 8 (1939), pp. 1172–77, Fig. 10.

[53] A. A. Baker, C. H. Dane, and J. B. Reeside, Jr., *op. cit.*

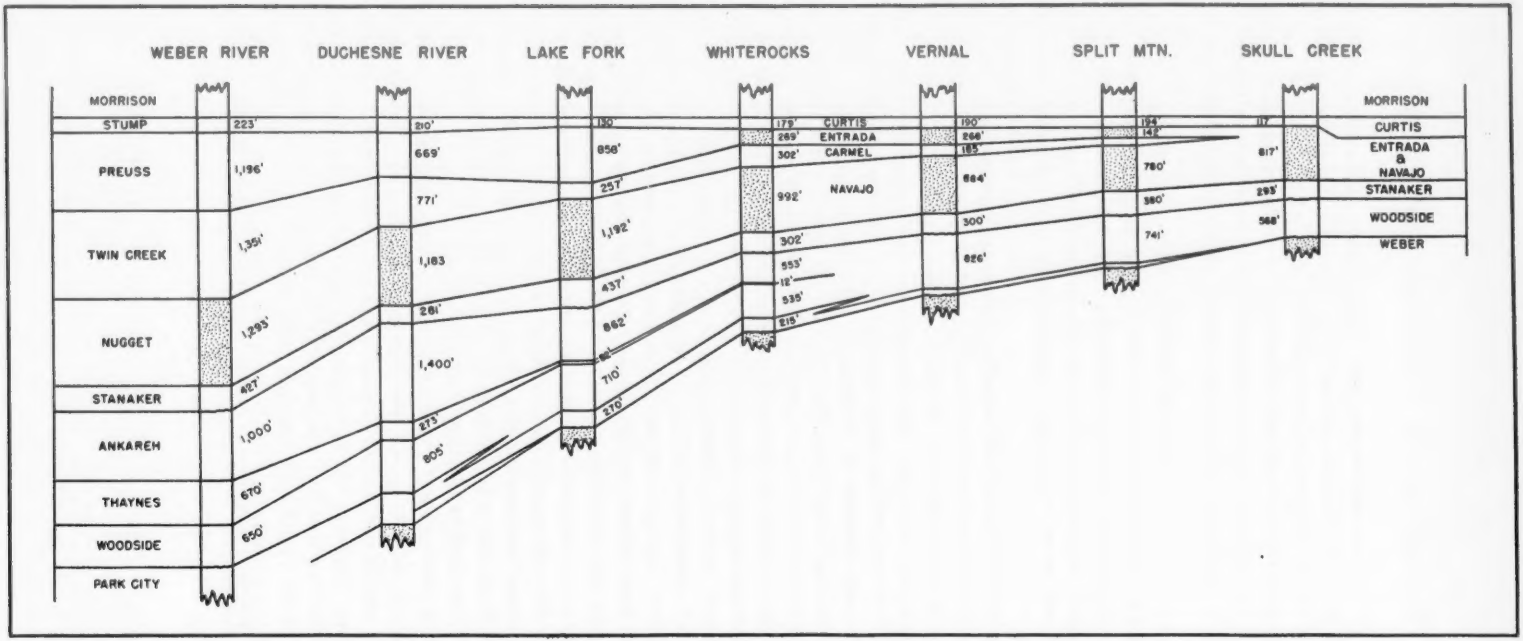


FIG. 8.—Correlation of formations along south flank of Uinta Mountains.

place between the Duchesne River (771 feet) and Lake Fork (257 feet). Between Lake Fork and Whiterocks Caynon, the Twin Creek is replaced by the Carmel redbeds, but thin tongues of marine limestone extend eastward as far as Deep Creek, where *Trigonia* was found in a 10-foot limestone separated from the Navajo sandstone by 30 feet of red shale. This bed was traced eastward as far as Stanaker Draw, north of Vernal, by R. W. Burns,[54] who reports that it is fossiliferous throughout that area. In the Vernal area the Carmel is mainly redbeds, with gypsum or lighter-colored beds in places. The Carmel thins eastward from Whiterocks Canyon and is absent in the section on Skull Creek, although Heaton found it present but very thin in that area, probably at a point west of the place where the writers measured their section. At Vermilion Creek, the Carmel consists of 20 feet of red shale which was included by Sears[55] in the Nugget sandstone. East of the wedge-edge of the Carmel, the cross-bedded Entrada sandstone, which overlies the Carmel in the eastern part of the Uinta Mountains, rests directly on the Navajo sandstone and, because of lithologic similarity, there is no apparent demarcation between the two sandstones.

On the north flank of the mountains, near Manila, the Carmel comprises 324 feet of redbeds and gypsum, with fossiliferous beds near the base containing *Camptonectes*, and *Trigonia*.

Preuss redbeds and Entrada sandstone.—Along the Weber River, at the western end of the Uintas, the Twin Creek is overlain by about 1,200 feet of redbeds which are not well exposed and which represent the Preuss formation of southeastern Idaho. These beds apparently comprise unit No. 7 of Stanton's section[56] published in 1893. The Preuss thins eastward and on Farm Creek, near the Duchesne River, is well exposed and comprises 669 feet of pink-red shales, siltstones, and very fine-grained sandstones. The Preuss thickens to 858 feet at Lake Fork. The writers believe that there the lower part represents the upper Twin Creek of sections on the west and is, therefore, related to the Carmel, but because of poor exposures at Lake Fork there is difficulty in separating the Preuss redbeds from Carmel redbeds (Fig. 6). East of Lake Fork the Preuss is replaced by a facies of decidedly different lithologic character—the cross-bedded Entrada sandstone. The main difference between the two is that the Preuss consists of silty plane-bedded redbeds and the Entrada is a cross-bedded clean quartz sandstone which is pink or white in color. Baker, Dane and Reeside[57] have shown that the Entrada of southern Utah comprises two facies—a red earthy sandstone facies on the west which grades into a cross-bedded sandstone facies on the east. This gradation is probably comparable with that between the Preuss and the Entrada along the Uintas. The Entrada persists eastward with but little change until it merges with

[54] R. W. Burns, personal communication (1941).

[55] J. D. Sears, *op. cit.*, p. 280.

[56] T. W. Stanton, "The Colorado Formation and Its Invertebrate Fauna," *U. S. Geol. Survey Bull. 106* (1893), p. 44.

[57] A. A. Baker, C. H. Dane, and J. B. Reeside, Jr., *op. cit.*, Fig. 12, p. 49.

the Navajo because of the thinning-out of the intervening Carmel. In the Vermilion Creek section the Entrada was included in the Nugget by Sears.[58]

At Manila, on the north flank of the mountains, the Entrada shows a composite of the two lithologic types; a lower unit made up mainly of typical cross-bedded Entrada sandstone and an upper unit made up mainly of pink-red siltstone representing the Preuss lithology (Fig. 9).

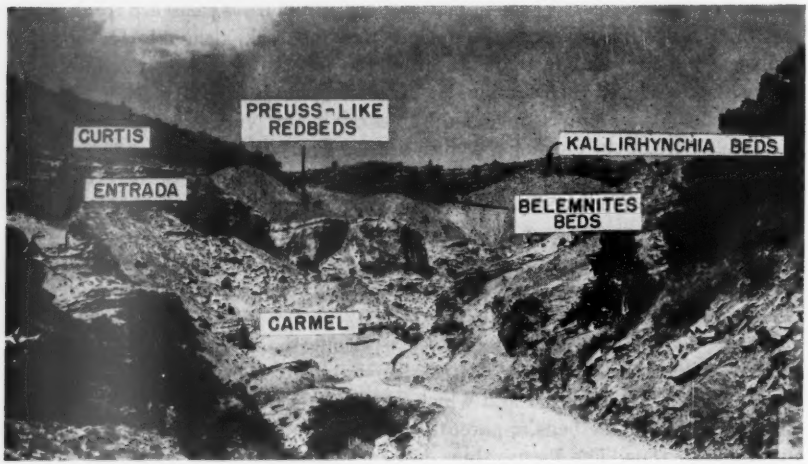


FIG. 9.—Jurassic formations exposed along Manila-Vernal road about 5 miles south of Manila, Utah.

Stump sandstone and Curtis formation.—Along the Weber River the Preuss is overlain by 223 feet of sandstones and shales which were classed as Stump by Heaton,[59] and as Curtis (?) by Eardley.[60] Although Stanton[61] reported *Trigonia* from this unit nearly 50 years ago, no later paleontologic evidence has been given to confirm the Stump, or Curtis, age of the beds. After much searching the writers were able to find three specimens of *Belemnites densus*,[62] and this fossil is abundant in a widespread zone over parts of Utah, Idaho, Colorado, Wyoming, and Montana. *Belemnites densus* has been reported from the type Stump of Idaho and was

[58] J. D. Sears, *op. cit.*, p. 280.

[59] Ross L. Heaton, *op. cit.*, Fig. 10.

[60] A. J. Eardley, *op. cit.*, pp. 837–38.

[61] T. W. Stanton, *op. cit.*, p. 44.

[62] *Belemnites densus* has recently been referred by various authors to the genus *Pachyteuthis*, but for the time being the writers prefer to retain the more familiar name for this well known index fossil.

found by the writers in the Stump or in the Curtis of every section studied around the Uinta Mountains. The name, Stump, is used by the writers in the Weber River, the Duchesne River, and Lake Fork areas so that the southeastern Idaho Jurassic terminology is uniformly used in all the western sections. East of Lake Fork, however, the name, Curtis, is used and along the eastern part of the mountains the lithologic character is somewhat different from that on the west. In general the Curtis is made up of a basal medium-grained to coarse-grained cross-bedded sandstone which rests with sharp contact on the subjacent beds. The middle part of the formation is greenish gray shale with intercalated fossiliferous sandstones, limestones, and coquinal limestones. The Curtis at Whiterocks Canyon and near Vernal and Manila has a conspicuous limestone member at the top which is characterized by abundant specimens of the brachiopod genus *Kallirhynchia*. Glauconite is one of the characteristic features of the Curtis and occurs as small nodules or grains in sandstones, shales, or limestones. The Twin Creek of Sears' Vermilion Creek section[63] is the Curtis; *Kallirhynchia* occurs at the top and *Belemnites* is abundant farther down.

There is a suggestion of an unconformity at the base of the Stump or Curtis. In the SW. $\frac{1}{4}$ of Sec. 30, T. 1 N., R. 6 W., between Lake Fork and the Duchesne River, the basal Stump rests on an irregular surface below which about 2 feet of upper Preuss is truncated in a horizontal distance of about 50 feet. J. C. Hazzard[64] has reported that there is a similar relation near the W. $\frac{1}{4}$ corner of Sec. 10, T. 1 S., R. 9 W., where at least 50 feet of upper Preuss is cut out below the basal contact of the Stump over a distance of about $\frac{1}{2}$ mile.

Morrison formation.—The stratigraphy of the Morrison formation along the Uinta Mountains and in contiguous areas has been described recently by Stokes.[65]

Correlation with Wyoming Jurassic rocks.—Since the Jurassic units in the Manila section, on the north flank of the Uintas, can be confidently correlated with those on the south flank, that section serves as a key in correlating the Jurassic formations of central Utah, described by Baker, Dane, and Reeside,[66] with those in Wyoming to the north of the Uintas.

Thomas examined cores from the Jurassic section in the Selegna Petroleum Corporation's Hardy well No. 1 in Sec. 11, T. 20 N., R. 104 W., in the North Baxter Basin gas field in Wyoming, about 60 miles north of the Manila section. Although coring was not continuous, the following units were differentiated.

MORRISON: Variegated shale
CURTIS: About 120 feet thick; glauconitic limestones, shales and sandstones; *Kallirhynchia* not far below top
ENTRADA: About 95 feet thick; gray sandstone

[63] J. D. Sears, *op. cit.*, p. 280.

[64] J. C. Hazzard, personal communication (1941).

[65] W. L. Stokes, "Morrison and Related Deposits in and adjacent to the Colorado Plateau," *Bull. Geol. Soc. America*, Vol. 55 (1944), pp. 951–92.

[66] A. A. Baker, C. H. Dane, and J. B. Reeside, Jr., *op. cit.*

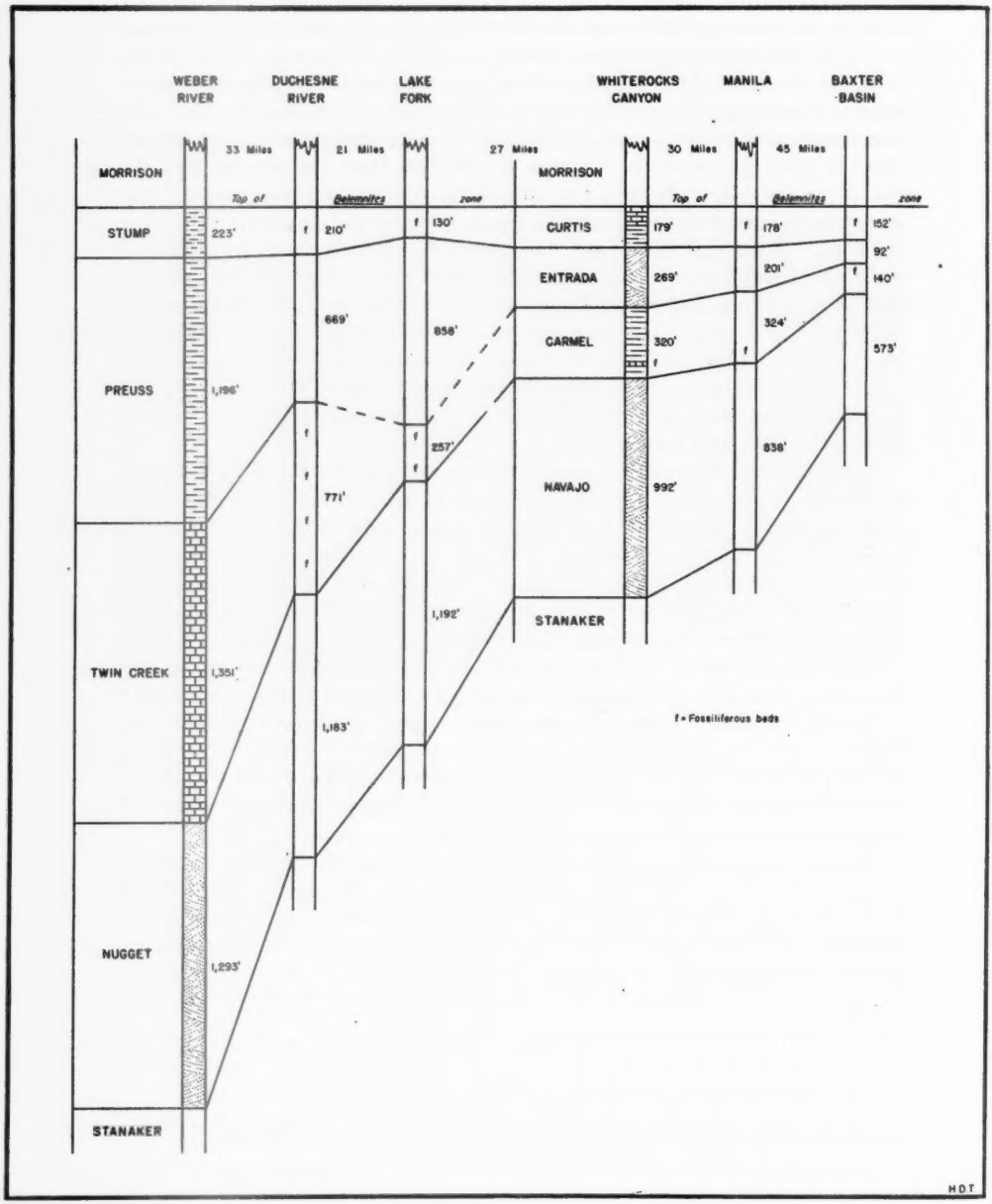


FIG. 10.—Correlation of Jurassic formations between Uinta Mountains and Baxter Basin gas field, Wyoming.

TWIN CREEK OR CARMEL: At top; about 100 feet of dark limestones and calcareous shales with fragments of marine fossils; lower part, 75 feet of red and green shales with a 5-foot bed of anhydrite. A 50-foot gap intervened between these cores and those representing the subjacent formation
NUGGET OR NAVAJO: 200 feet plus; gray sandstone

In March, 1941, a group of geologists[67] met to study cores from the Red Desert Oil Company's Edith Aspden well No. 1 in Sec. 34, T. 18 N., R. 103 W., in the South Baxter Basin field. The following lithologic descriptions were prepared by W. T. Nightingale for the units differentiated (Fig. 10).

CURTIS: 152 feet; glauconitic greensands and sandy limestones with some oölitic limestone layers; grayish green sandy shale at base; *Belemnites densus* present
ENTRADA: 92 feet; gray to white medium fine-grained sandstone
TWIN CREEK: 140 feet; upper part microcrystalline limestone with argillaceous limestone and shale partings; middle part greenish gray silty calcareous shale; lower part brown microcrystalline limestone with green shale partings
NUGGET: 573 feet; light-colored massive medium-grained sandstone
JELM (Stanaker equivalent): 380 feet; upper 170 feet, green dolomitic shales and brown silty dolomite; middle 150 feet, maroon silty shale; basal 60 feet, white fine- to medium-grained sandstone containing pink feldspar grains in lower part

It is evident, therefore, that both Twin Creek and Carmel lithologic types are present in the Baxter Basin area; the Twin Creek type represented by dark fossiliferous limestones and the Carmel type by red and green shales and anhydrite.

Recently Love *et al.*[68] and Imlay[69] have discussed the Jurassic formations of the Wind River Basin in central Wyoming, north of the Baxter Basin field, recognizing Nugget sandstone at the base overlain by Gypsum Spring, lower Sundance, upper Sundance, and Morrison. It is suggested on the basis of stratigraphic sequence and lithologic similarity that the Navajo, Carmel, Entrada, and Curtis of the Manila area are to be correlated with the Nugget, Gypsum Spring, lower Sundance, and upper Sundance of the Wind River Basin. There can be little question of the correlation of Navajo with Nugget and of Curtis with Upper Sundance. There is some question, however, on the correlation of the Carmel with the Gypsum Spring and the Entrada with the lower Sundance. Because the Carmel and the Gypsum Spring are both gypsiferous redbed sequences resting directly on the Navajo or Nugget sandstone, the writers would correlate these units. Imlay, however, on a paleontologic basis, correlates the Carmel of central Utah with the lower Sundance of the Wind River Basin, rather than with the Gypsum Spring.[70]

[67] A. E. Brainerd, S. H. Knight, C. S. Lavington, R. W. Mallory, W. T. Nightingale, J. B. Sansone, R. L. Sielaff, and H. D. Thomas.

[68] J. D. Love *et al.*, "Stratigraphic Sections and Thickness Maps of Jurassic Rocks in Central Wyoming," *U. S. Geol. Survey Prelim. Chart 14*, Oil and Gas Inves. (1945).

[69] Ralph W. Imlay, "Occurrence of Middle Jurassic Rocks in Western Interior of the United States," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 29, No. 7 (1945), pp. 1019–27.

[70] Ralph W. Imlay, *op. cit.*, Table 1.

STRATIGRAPHIC SECTIONS

Weber River Section

Stratigraphic section measured on east side of Weber River, just north of Peoa, T. 1 S., R. 5 E., Summit County, Utah, by Horace D. Thomas and Max L. Krueger.

	Thickness in Feet
Lower Part of Morrison	
Red, lavender, and mauve clay shales with purple, tan, or white sandstones which vary in texture from fine-grained to conglomeratic. Limestone noduels common in clay shales at certain horizons and polished pebbles (gastroliths?) in middle of interval	432
Light gray dense crinkly algal (?) limestone	2
Red shale	2
Gray siliceous algal (?) limestone with questionable fossil fragments	1
Pink shale	3
Stump	
Greenish gray to tan hard fine-grained quartzitic sandstone; upper 4 feet calcareous, with obscure fragments of fossil shells; *Belemnites densus* rare	40
Gray to tan flaky shales, sandy shales, and thin sandstones	142
Flesh-colored soft platy cross-bedded medium-grained sandstone	41
Thickness of Stump	223
Preuss	
Poorly exposed pink-red siltstones and very fine-grained sandstones	1,196
Thickness of Preuss	1,196
Twin Creek	
Drab-gray very calcareous shale with interbedded thin flesh-colored limestones and thin fine-grained sandy limestones	211
Drab-gray calcareous shale, weathering splintery, with a few thin limestones	420
Platy thin-bedded to shaly limestone and sandy limestone weathering tan and gray	36
Light gray soft massive claystone	6
Medium dark gray calcareous shale, weathers splintery	45
Tan thin-bedded very fine-grained sandy limestone	40
Gray calcareous shale with two thin beds of red shale	72
Gray to blue thin-bedded to shaly limestone and calcareous shale with layers of coquinal limestone made up of small gastropods and *Pentacrinus* columnals; thin-bedded parts dense and brittle	521
Thickness of Twin Creek	1,351
Nugget	
Salmon-pink quartzitic sandstone, incompletely exposed	

Stratigraphic section measured from Mahogany Hills, north of the Weber River, to the mouth of Franson Canyon, south of the Weber River, T. 1 S., R. 6 E., Summit County, Utah, by Horace D. Thomas and Max L. Krueger.

	Thickness in Feet
Twin Creek	
Basal part gray to blue thin-bedded limestone and calcareous shale	
Nugget	
Salmon-pink massive cross-bedded friable medium-grained sandstone	1,293
Thickness of Nugget	1,293
Stanaker	
Mainly covered; pink and gray platy thin-bedded ribbon limestone at top just below Nugget; lower part shows isolated exposures of bright red platy sandstones, gray and red mottled massive sandstones, red siltstones, and bright red shales	394

	Thickness in Feet
Gartra grit member: Gray coarse-grained feldspathic quartz grit with scattered quartz pebbles ranging up to ½-inch in diameter; quartzitic, resistant, and forms a ridge	33
Thickness of Stanaker	427

ANKAREH

Redbeds, not well exposed; mainly red thin-bedded fine-grained sandstones and siltstones. (After completion of field work and during computation of thicknesses, it became apparent that two measurements made across the Ankareh were in disagreement. The two measurements averaged 1,000 feet, and that figure is here used.)	1,000
Thickness of Ankareh	1,000

THAYNES

Upper part, gray, tan, and brown platy limestones and tan, yellow, and gray sandstones, all fossiliferous; lower part, gray limestone weathering gray and dark brown, thin- to heavy-bedded, dense or very finely crystalline, with abundant fossils at certain levels	670
Thickness of Thaynes	670

WOODSIDE

Dark red shales, siltstones and fine- to medium-grained sandstones; some beds very micaceous, some ripple-marked; near middle is a 50-foot pink cross-bedded medium-grained ridge-forming sandstone	650
Thickness of Woodside	650

PARK CITY

Pink and white mottled limestone at top; next below is blue-gray and lavender limestone with *Punctospirifer pulcher* and numerous bryozoans; next below is gray cherty limestone; lower half of unit comprises medium-grained sandstones, cherty sandstones, gray very cherty limestone, and bedded chert	307
Black fetid phosphatic shale with abundant *Nucula* (?) in lower few inches; in talus are fragments of dark dense limestone and of oölitic phopshate rock	45
Black fossiliferous chert	3
Dark gray heavy bedded cherty quartzite with geodes, chert laminae and nodules, and beds of silicified coquina, one as much as 5 feet thick; *Schizodus* common; one specimen of shark denticles	41
Covered; an isolated exposure about 150 feet stratigraphically below top is a gray cherty limestone with *Orbiculoidea utahensis.*	

DUCHESNE RIVER SECTION

Stratigraphic section measured along Farm Creek in southern part of T. 1 N., R. 7 W., and northern part of T. 1 S., R. 7 W., several miles west of Hanna, Duchesne County, Utah, by Horace D. Thomas.

	Thickness in Feet
LOWER PART OF MORRISON	
Red shale with several beds of white medium-grained sandstone	533
STUMP	
Dark gray flaky shale	5
Yellow soft friable fine-grained sandstone	22
Dark gray shales with thin beds of coquinal limestone and of fine-grained glauconitic sandstone; *Belemnites densus* and other typical Stump fossils common	111
Yellowish gray heavy bedded cross-laminated ripple-marked friable medium- to coarse-grained sandstone; upper part softer than basal part which forms a cliff	72
Thickness of Stump	210

	Thickness in Feet
PREUSS	
Pink-red very fine-grained sandstone with intercalated beds of thin-bedded siltstone and of red shale	285
White massive fine-grained sandstone	4
Pink-red massive to thin-bedded fine- to medium fine grained sandstone with interbedded siltstones at top; downward becomes less sandy and lower part is pink-red soft blocky siltstone with some shaly beds	380
Thickness of Preuss	669
TWIN CREEK	
Gray and greenish gray platy finely laminated calcareous shale	68
Gray shale with thin layers of brown finely laminated siltstone	4
White massive fine-grained calcareous sandstone	8
Greenish gray and red shales with thin beds of brown platy limestone	114
Greenish gray thin-bedded to finely laminated sandy limestones, calcareous siltstones, and sandy shales	109
Light gray, greenish gray and grayish green thin-bedded to finely laminated sandy limestones, calcareous shales and calcareous siltstones with several thin red shale layers; some beds ripple-marked	204
Light gray thin-bedded dense porcellaneous limestone	105
Red shale	10
Dark gray fossiliferous thin-bedded oölitic limestone, finely crystalline limestone, and shaly limestone, all weathering light gray; upper 20-feet platy and forms a ledge; *Pentacrinus* and other Twin Creek fossils common	149
Thickness of Twin Creek	771
NUGGET	
Sandstone, uppermost part lavender, hard and cross-bedded; 15 feet near top bright red and plane-bedded; major part salmon-pink massive cross-bedded sandstone	1,183
Thickness of Nugget	1,183
STANAKER	
Red flaky shale	2
Greenish gray thin-bedded fine-grained sandstone; grades down into subjacent bed	1
Salmon-pink thin-bedded fine-grained sandstone; resistant and caps a hogback	5
Apple-green flaky shale	9
Green, brown, and red mottled thin-bedded very fine-grained calcareous sandstone	4
Pink massive clayey siltstone	11
Redbeds, covered, petrified wood in float near base; ½ mile to west ocher beds lie in part of this interval	223
Gartra grit member: Mottled gray and pink cross-bedded quartz grit with scattered quartz pebbles ranging up to ½ inch in diameter; hard and firmly cemented; forms a hogback	26
Thickness of Stanaker	281
ANKAREH	
Redbeds; not measured. W. C. Rauch measured an interval of 1,680 feet between base of Nugget and top of Thaynes several miles west of Farm Creek.	

Stratigraphic section measured along the Duchesne River, north of Hanna, in T. 1 N., R. 8 W., Duchesne County, Utah, by W. C. Rauch and checked in the field by Horace D. Thomas and Max L. Krueger.

	Thickness in Feet
ANKAREH	
Brick-red shale, sandy shale, and very fine-grained red sandstone with several thin white sandstones. Exact thickness not determined, but interval from base of Nugget to top of	

	Thickness in Feet
Thaynes measured 1,680 feet. If thickness of Stanaker on Farm Creek (281 feet) be subtracted, approximate thickness of Ankareh is 1,400 feet	1,400
Thickness of Ankareh	1,400
THAYNES	
Tan to gray thin-bedded to thick-bedded sandy limestone with thin layers of calcareous sandstone; abundant fossils	273
Thickness of Thaynes	273
WOODSIDE	
Red sandy shales and thin-bedded sandstones, some ripple-marked, with several thin lighter-colored sandstone beds	805
Thickness of Woodside	805
PARK CITY	
Gray to creamy limestone, cherty limestone and geodal shaly limestone with a redbeds unit about 50 feet thick near middle; thickness estimated	300
Black phosphatic shale with beds of black limestone and nodular phosphate rock; thickness estimated	40
Tan sandy limestones, cherty limestones, and very fine-grained quartzites; thickness estimated	100
Approximate thickness of Park City	440
WEBER	
Sandstone, not measured	

LAKE FORK SECTION

Stratigraphic section measured along Lake Fork in Ts. 1 and 2 N., R. 5 W., Duchesne County, Utah, by Horace D. Thomas. Lower Morrison and Curtis measured on west side of Lake Fork in Sec. 2, T. 1 N., R. 5 W. Section from Curtis through Park City measured from NW. ¼ of Sec. 1, T. 1 N., R. 5 W., northward to Mackentire Draw in Sec. 26, T. 1 N., R. 5 W.

	Thickness in Feet
LOWER PART OF MORRISON	
Bright red flaky shale with one-inch layers of light gray sandstone in upper part	49
Olive-green flaky shale	3
STUMP	
Light gray massive cross-bedded medium-grained calcareous sandstone	19
Gray shale, not well exposed; contains *Belemnites densus;* on east side of river this interval is composed of gray shale with gray fossiliferous glauconitic sandstones and coquinal limestones	79
Gray heavy-bedded to thin-bedded ripple-marked medium-grained sandstone; on east side of river *Eumicrotis curta* is abundant in parts of this bed; *Camptonectes* also occurs	32
Thickness of Stump	130
PREUSS	
Redbeds, poorly exposed; isolated exposures show pink-red fine-grained shaly sandy siltstone and some light gray and greenish gray very fine-grained shaly sandstones and sandy shales	858
Thickness of Preuss	858
TWIN CREEK	
Light gray heavy bedded sandy limestone with coquinal layers made up almost entirely of *Trigonia* sp.; large *Camptonectes* and frilled *Ostrea* also occur in this bed	4
Poorly exposed pink very fine-grained siltstone, red shale, and gray shale	91

	Thickness in Feet
Gray, tan and pink dense limestone	30
Light gray porcellaneous limestone with interbedded shaly limestone and gray calcareous shale; carries *Pentacrinus, Camptonectes, Ostrea,* and minute gastropods	53
Light gray dense porcellaneous limestone at top grading down into heavier-bedded limestone which becomes thin-bedded and very sandy in lower 8 feet	79
Thickness of Twin Creek	257
NUGGET	
Gray to white massive cross-bedded medium-grained sandstone weathering creamy colored to tan; generally resistant but with softer parts	1,192
Thickness of Nugget	1,192
STANAKER	
Greenish gray sandy shale or shaly sandstone becoming red toward base; not well exposed	43
Pink-red thin-bedded fine-grained sandstone; forms ledges	41
Light gray dense heavy-bedded fine-grained sandstone	16
Redbeds, poorly exposed, mainly talus covered	269
Gartra grit member: Gray medium- to coarse-grained sandstone which downward becomes light gray to tan coarse-grained quartz grit and conglomeratic grit; basal part most conglomeratic, with quartz pebbles as large as 1 inch in diameter	67
Thickness of Stanaker	437
ANKAREH	
Olive-gray siltstone, grades downward into subjacent bed	10
Red siltstone and very fine-grained sandstone	114
Gray massive cross-laminated medium-grained sandstone with small calcitic pisolitic concretions	7
Red shale	16
Light gray medium-grained sandstone with small calcitic pisolitic concretions	11
Red flaky shales, finely laminated siltstones, and thin-bedded very fine-grained ripple-marked sandstones	415
White gypsum	4
Red siltstones and very fine-grained sandstones	285
Thickness of Ankareh	862
THAYNES	
White to light gray thin-bedded very fine-grained very calcareous sandstone and sandy limestone; forms ridge with subjacent bed	26
Light gray to tan thin- to heavy-bedded limestone and sandy limestone, resistant and forms a ridge; no fossils noted	56
Thickness of Thaynes	82
WOODSIDE	
Red thin-bedded siltstones and very fine-grained sandstones	316
White to light gray thin-bedded very fine-grained sandstone	15
Red flaky shales and siltstones	14
Greenish gray very fine-grained ripple-marked micaceous sandstone; hard and resistant	3
Red to maroon shales, siltstones and very fine-grained sandstones	357
Tawny to drab siltstone	5
Thickness of Woodside	710
PARK CITY	
Light gray dense limestone 5 feet thick at top; 70 feet cherty limestone and creamy chert next below; 10 feet lavender cherty limestone at base	85

	Thickness in Feet
Mackentire redbeds tongue of Woodside: Bright red shales, siltstones and very fine-grained sandstones	56
Yellowish cherty limestone and chert	67
Black shale with layers of phosphate rock and with beds of dense black limestone 1 to 5 feet thick in middle	62
Thickness of Park City	270

WEBER

Buff hard dense cross-bedded medium-grained sandstone; not measured

WHITEROCKS CANYON SECTION

Stratigraphic section measured on west side of Whiterocks River in SW. ¼ of Sec. 18 and NW. ¼ of Sec. 19, T. 2 N., R. 1 E., Uintah County, Utah, by Horace D. Thomas. Section of Jurassic rocks was also measured on east side of river in SE. ¼ of Sec. 18, T. 2 N., R. 1 E.

	Thickness in Feet
TERTIARY COVER	
CURTIS	
Gray thin-bedded cross-bedded oölitic fossiliferous limestone, parts sandy, *Kallirhynchia* sp. abundant	50
Gray shale with thin fossiliferous limestone beds ranging from a few inches to several feet in thickness; *Belemnites densus*	91
Gray thin-bedded cross-bedded medium- to coarse-grained sandstone; on the east side of the canyon this bed has a 1-foot chert pebble conglomerate at top	38
Thickness of Curtis	179
ENTRADA	
Soft pink-red very fine-grained silty sandstone and white very fine-grained sandstone; interval not well exposed but pink-red and white beds seem interbedded in about equal thicknesses	269
Thickness of Entrada	269
CARMEL (Measured on east side of river)	
Red shale and gray shale, very poorly exposed; this interval contains beds of gypsum on west side of river	181
White massive gypsum	5
Red shale	25
White massive gypsum	15
Red, gray and olive-green shales and sandy shales	21
Limestone; upper 10 feet light gray thin-bedded dense porcellaneous limestone; middle 3 feet gray calcareous shale; basal 4 feet very fossiliferous oölitic limestone in 6-inch beds; abundant *Trigonia* sp.	17
Gray, red and olive-green shales	40
Tan coquinal limestone with abundant *Camptonectes* sp.	1
Dark gray flaky shale becoming lighter in color and clayey near base	15
Thickness of Carmel	320
NAVAJO	
Dark, massive cross-bedded medium fine-grained tar-saturated sandstone; saturation is essentially complete and only where there are small calcitic concretions, small quartzitic patches, or tightly cemented ¼-inch laminae, is rock unsaturated	992
Thickness of Navajo	992

	Thickness in Feet
STANAKER	
Covered interval; suggestion of red, lavender, and ocher beds	259
Gartra grit member: Tan heavy-bedded cross-laminated coarse-grained quartz grit with sporadic quartz pebbles and here and there gray chert pebbles up to 1-inch in diameter	43
Thickness of Stanaker	302
ANKAREH	
Redbeds, very poorly exposed	553
Thickness of Ankareh	553
THAYNES	
White thin-bedded very fine-grained sandy limestone in beds from 1 to 2 feet thick, with interbedded red siltstones; two-thirds of interval is limestone; poorly preserved high-spired gastropods in basal limestone	12
Thickness of Thaynes	12
WOODSIDE	
Red shales and siltstones; lower part covered	535
Thickness of Woodside	535
PARK CITY	
Gray cherty limestone and bedded chert; forms ridge	68
Bright red sandy shale with small circular white spots; lower part covered in strike valley	58
Upper part; tan limestone, sandy limestone and sandstone; all cherty and with bedded chert at top; contains *Plagioglypta;* lower part greenish gray shales and siltstones, silicified oölites, and black phosphate rock, lithologic details not discernible	89
Thickness of Park City	215
WEBER	
Gray hard medium-grained sandstone cut by secondary quartz veinlets; some parts of upper 100 feet quartzitic; not measured	

VERNAL SECTION

Stratigraphic section measured north of Vernal, Uintah County, Utah, from Sec. 7, T. 3 S., R. 22 E., northward to a gorge tributary to gorge of Brush Creek near NW. cor. of Sec. 32, T. 2 S., R. 22 E., and west of the Vernal-Manila highway, by Horace D. Thomas.

	Thickness in Feet
LOWER MORRISON	
Variegated mauve, lavender, and maroon clay shales with thin brown lenticular sandstones and thin beds of chert pebble conglomerate	
CURTIS	
Gray thin bedded cross-laminated oölitic sandy limestone	5
Gray shales interbedded with thin gray sandy limestones	31
Gray thin-bedded cross-laminated oölitic limestone with abundant specimens of *Kallirhynchia*	12
Dark gray flaky shale and sandy shale with thin layers of gray sandstone and coquinal limestone in upper half; lower half much darker flaky shale; *Belemnites* present throughout	75
Gray soft coarse-grained glauconitic sandstone; thin beds of gray sandy shale in upper part	67
Thickness of Curtis	190
ENTRADA	
Pink, red or tan very soft, very fine-grained sandstone; not well exposed	197
White to tan very soft, almost unconsolidated, fine-grained sandstone	71
Thickness of Entrada	268

	Thickness in Feet
CARMEL	
Red and greenish shales alternating in about equal parts; red at top, then gray, then red, gray at base	85
White soft medium fine-grained sandstone	3
Red shale	3
Gray shale	5
Bright red shale and siltstone	89
Thickness of Carmel	185
NAVAJO	
Gray to cream to buff massive cross-bedded medium fine-grained sandstone weathering into knobs and turrets	884
Thickness of Navajo	884
STANAKER (Type section)	
Lavender clay shale	28
Tan thin-bedded medium-grained sandstone	5
Lavender clay shale	4
Red to tan heavy bedded to thin-bedded medium fine-grained sandstone; some parts silty and weather more readily; forms hogback	65
Red siltstone	3
Red thin-bedded fine-grained sandstone	6
Lavender and ocher clay shale with two 3-foot beds of massive medium-grained red sandstone	65
Yellow to ocher soft massive very calcareous sandstone and sandy limestone	4
Lavender and purple clay shale with thin red soft massive very fine-grained sandstones	34
Gray coarse-grained feldspathic quartz grit; locally quartzitic	3
Lavender clay shale	13
Gray coarse-grained feldspathic quartz grit	4
Lavender clay shale	6
Gartra grit member: Gray massive cross-bedded feldspathic quartz grit with sporadic quartz pebbles up to one inch in diameter; resistant and forms a hogback; rests on irregular surface truncating subjacent red Woodside shales; locally varies from 40 to 80 feet in thickness	60
Thickness of Stanaker	300
WOODSIDE	
Dark red shales, siltstones and very fine-grained sandstones	477
Tan, gray and red thin-bedded to finely laminated ripple-marked very fine-grained calcareous sandstone grading down into olive-gray shale	49
Tan thin-bedded to finely laminated very fine-grained calcareous sandstone	12
Gray to tan flaky shale	30
Red shale	10
Gray to tan flaky shale	43
Red flaky shale; within 500 feet along strike becomes gray	10
Olive-gray and tan flaky shale with thin slabby sandy beds	72
Brown thin-bedded ripple-marked very fine-grained calcareous sandstone; forms a ledge	6
Olive-gray and tan flaky shale with several thin brown platy very fine-grained sandstones	117
Thickness of Woodside	826
PARK CITY	
Gray heavy bedded dense limestone with much gray chert	6
Greenish gray flaky shale	5
Gray dense cherty limestone	7
Olive-gray shale at top grading downward into red shale below; about 10 feet thin-bedded yellow ocher siltstone at base	26
Gray thick-bedded limestone and sandy limestone with chert nodules and bedded chert; calcite geodes throughout; upper 5 feet with abundant *Plagioglypta* and *Euphemites*	25

	Thickness in Feet
Dark greenish gray and black phosphatic shale and thin beds of oölitic phosphate rock; upper part somewhat sandy and cherty, with quartz geodes	22
Thickness of Park City	91

WEBER

Creamy to tan massive cross-bedded medium-grained quartz sandstone; not measured

SPLIT MOUNTAIN SECTION

Stratigraphic section measured near mouth of gorge of Green River at Split Mountain, several miles east of Dinosaur National Monument, approximately along line between T. 5 S., R. 23 E., and T. 5 S., R. 24 E., Uintah County, Utah, by Horace D. Thomas.

	Thickness in Feet
LOWER MORRISON	
Variegated lavender, mauve, gray and green clay shale	
CURTIS	
Gray ripple-marked fine-grained sandstones with interbedded gray sandy shales	78
Dark gray fissile shale containing *Belemnites densus* and other typical Curtis invertebrates	36
Gray heavy bedded to thin-bedded medium- to coarse-grained sandstone	60
Sandstone similar to above but thin layers of gray fissile shale	10
Gray heavy bedded to thin-bedded coarse-grained sandstone with impressions of pelecypods; contact with subjacent bed sharp	10
Thickness of Curtis	194
ENTRADA	
White to red sandstone, mottled on a large scale, which is soft, massive, cross-laminated and fine-grained; weathers into rounded domes, not along bedding planes	142
Thickness of Entrada	142
CARMEL	
Bright red shales, siltstones and very fine-grained sandstones with two 10- to 15- foot beds of gray shale	104
Thickness of Carmel	104
NAVAJO	
Tan soft massive cross-bedded fine- to medium-grained sandstone which weathers into smooth knobs and domes; basal contact sharp	780
Thickness of Navajo	780
STANAKER	
Lavender-red fine-grained sandstones and shales about 70 feet thick at top; red soft fine-grained sandstones with interbedded red shales aggregating about 70 feet in thickness in middle; lower part consists of lavender, red, and ocher shales	287
Gartra grit member: Gray cross-bedded coarse-grained quartz grit and conglomerate; parts are well sorted fine- to medium-grained sandstone, others are granule grits with angular to poorly rounded sporadic quartz pebbles up to 1 inch in diameter; resistant and forms hogback; rests with sharp irregular contact on subjacent bed	93
Thickness of Stanaker	380
WOODSIDE	
Brick-red to bright red shales and siltstones, with several thin harder very fine-grained sandstones	502
Brownish red massive medium- to fine-grained sandstone; forms a ledge	10
Brownish red thin-bedded to finely laminated siltstone and very fine-grained sandstone with about a dozen 1- to 4-inch gray, olive-green or tan layers	51

	Thickness in Feet
Gray, tan, and ocher firm platy claystone and siltstone with some red layers and red mottling	12
Red shale with several thin gray, yellow, or ocher sandy shales, calcareous shales and very fine-grained sandstones	113
Yellowish-tan calcareous micaceous siltstone	4
Red shale with thin very fine-grained sandstone layers	19
Yellow shaly mudstone	15
Yellowish gray massive very fine-grained sandstone with thin shale layers	15
Thickness of Woodside	741

PARK CITY

Gray massive sandy limestone	2
Light gray to tan platy dense limestone with gray chert layers and nodules; lower part shaly	32
Gray thin-bedded to heavy bedded very sandy limestones, limy sandstones and dense gray limestones with large brown chert nodules and layers; contains *Plagioglypta* and *Euphemites* in upper half	42
Thickness of Park City	76

WEBER

Gray massive cross-bedded sandstone with numerous small limy concretions which impart a pisolitic appearance to uppermost part; not measured

SKULL CREEK SECTION

Stratigraphic section measured on south flank of Skull Creek anticline in T. 4 N., R. 101 W., Moffat County, Colorado, by Max L. Krueger.

	Thickness in Feet
LOWER MORRISON	
Variegated clay shales	
CURTIS	
Gray shale	44
Brown soft shales with thin gray sandstones and fossiliferous limestones; *Belemnites densus* and other Curtis invertebrates present	73
Thickness of Curtis	117
ENTRADA AND NAVAJO	
White to buff cross-bedded fine- to medium-grained sandstone with 25 feet of harder ledge-forming sandstone at top	576
White dense limestone	2
White to buff cross-bedded fine- to medium-grained sandstone	239
Thickness of Entrada and Navajo	817
STANAKER	
Upper part brick-red massive silty sandstone; lower part dark purplish, light red and brick-red shales	213
Mottled purple hard sandy shale	14
Gartra grit member: Grayish white massive cross-bedded feldspathic grit and pebble conglomerate; 3 feet red shale near middle	66
Thickness of Stanaker	293
WOODSIDE	
Red shales, siltstones and very fine-grained sandstones; some greenish gray shales	257
Red thin-bedded platy fine-grained sandstone	23

	Thickness in Feet
Buff to gray gypsiferous clay shale with a few thin sandstones at top; lower part orange-yellow shale with interbedded thin tan siltstones; basal contact sharp	288
Thickness of Woodside	568

WEBER

White to buff massive cross-bedded sandstone; not measured

MANILA SECTION

Stratigraphic section measured on north flank of Uinta Mountains, south of Manila, Dagget County, Utah, by Horace D. Thomas. Specific localities as follows: Section from Morrison to Navajo measured adjacent to Manila-Vernal Highway in Sec. 6, T. 2 N., R. 20 E.; section of Navajo and Gartra measured in Sec. 3, T. 2 N., R. 19 E.; section of upper Woodside measured about 1 mile south of Horseshoe Canyon west of Green River in Sec. 3, T. 2 N., R. 20 E.; and section of lower Woodside and Park City measured along Hide Out Canyon road in Sec. 3, T. 2 N., R. 20 E.

	Thickness in Feet
LOWER PART OF MORRISON	
Variegated clay shale; not measured	
CURTIS	
Gray heavy to thin-bedded hard dense crystalline limestone with abundant specimens of *Kallirhynchia myrina* in upper part; forms dip-slope of hogback	68
Dark gray shale with thin interbedded limestones; abundant specimens of *Belemnites densus*	110
Thickness of Curtis	178
ENTRADA	
Pinkish red siltstones and very fine-grained sandstones	84
Yellow massive cross-bedded fine- to medium-grained sandstone; resistant and forms a cliff	72
Pinkish red soft massive very fine-grained sandstone	25
White- and pink-mottled massive fine-grained sandstone	20
Thickness of Entrada	201
CARMEL	
Red and gray flaky shale and siltstone	101
Light gray gypsum	3
Very light gray shale with thin beds of gypsum and gypsum veinlets	41
Light gray heavy-bedded gypsum	9
Brick-red and light gray shale, interbedded	31
Light gray massive gypsum	5
Brick-red flaky shale with several interbedded greenish-gray flaky shale beds and two 6-inch beds of light gray fine-grained very calcareous sandstone	86
Dark gray heavy bedded coquinal and oölitic limestone split by several dark shale layers	22
Gray shale with thin layers of coquinal limestone	16
Brown slabby fossiliferous shaly limestone with *Camptonectes*, *Trigonia* and *Ostrea*	3
Dark gray flaky shale	7
Thickness of Carmel	324
NAVAJO	
Light gray to tan massive cross-bedded well sorted fine-grained sandstone; forms cliff throughout area	838
Thickness of Navajo	838
STANAKER	
Tan sandy shale sharply overlain by Navajo sandstone	10
Apple-green flaky shale	2

	Thickness in Feet
Greenish gray thin-bedded shaly siltstone and very fine-grained shaly sandstone	24
Purplish red shale	10
Purplish red irregularly bedded medium-grained sandstone interbedded with red shale	64
Purplish red limestone pebble and clay pebble conglomerate	5
Purplish red flaky shale	46
Gray hard very coarse-grained quartz sandstone and quartz granule grit; poorly sorted	3
Purplish red shale	15
Lavender, mottled with gray, hard cross-laminated medium- to coarse-grained sandstone	10
Lavender to red flaky shale	95
Gartra conglomerate member: Purplish red limestone pebble conglomerate in lenses set in purplish red cross-bedded coarse-grained sandstone. Rests with sharp irregular contact on subjacent beds	18
Thickness of Stanaker	302

WOODSIDE

Red siltstone and very fine-grained sandstone with some red shale; weathers into a vertical scarp in places and is relatively resistant	349
Redbeds, softer than above and poorly exposed; weather with gypsum excrescence	245
Massive soft gypsum with thin breaks of bright-red shale	121
Tawny to greenish gray very fine-grained ripple-marked sandstones, limy sandstones, siltstones and micaceous shales, with thin beds of gypsum	406
Tan and gray fine-grained thin-bedded sandstones, sandy shales and siltstones; some beds calcareous; ripple-marks conspicuous; obscure molds of pelecypods in talus	239
Brown platy medium-grained sandstone	4
Tan to gray thin-bedded very fine-grained sandstones and sandy shales; basal contact sharp	91
Thickness of Woodside	1,456

PARK CITY

Light gray dense siliceous limestone and coquinal limestone; upper part thin-bedded, lower part heavy-bedded; carries abundant bryozoans and *Euphemites subpapillosus*	19
Light gray dense heavy-bedded limestone with calcite geodes, nodular gray chert, and layers of white to gray chert	40
Interbedded gray flaky shale and light gray dense argillaceous limestone with calcite geodes and nodular gray chert	45
Ocher to yellow soft massive siltstone	15
Red and gray sandy shale	10
Gray gypsum or anhydrite, lenticular	1
Tan cross-bedded medium- to coarse-grained quartzitic sandstone	15
Interbedded gray dense heavy-bedded very cherty limestone and gray fine-grained sandstones; some thin tan shale breaks; sandy parts contain calcite geodes; *Plagioglypta* in talus	108
Black to very dark gray shale and oölitic phosphate rock, details obscure, forms slope	22
(Note: Following beds probably equivalent to lower part of Park City of western Uintas)	
Cliff-forming massive sandstone unit consisting mainly of massive to irregularly bedded buff to yellow very fine- to fine-grained sandstone with calcite geodes in lower part. Vertical variation is such that parts are calcareous and others shaly with gradations between; some beds siliceous or quartzitic; irregular patches of brown chert in upper part	105
Brown massive cross-laminated sandstone superficially like Weber but differs in minor details; rests on an irregular surface which has several feet of relief and which abruptly truncates the cross-bedding of the subjacent Weber sandstone	10
Thickness of Park City	390

WEBER

Tan cross-bedded sandstone	

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VOL. 30, NO. 8 (AUGUST, 1946), PP. 1294-1305, 4 FIGS.

ELLIS, AMSDEN, AND BIG SNOWY GROUP, JUDITH BASIN, MONTANA[1]

PAUL T. WALTON[2]
Casper, Wyoming

ABSTRACT

Strata lying between the top of the middle Mississippian Madison limestone and the base of the Upper Jurassic Morrison formation in an area in central Montana are described and correlated. Sixteen columnar outcrop sections and six well sections are presented on three plates to show the lateral extent, thickness, and lithologic character of the Jurassic Ellis formation, the lower Pennsylvanian Amsden formation, the upper to middle Mississippian Big Snowy group.

The Big Snowy group, which is divided into the Heath, Otter, Kibbey and Charles formations in descending order, contains marine, fluvial and estuarine facies. It lies disconformably on the Madison in the southern part of the area. The upper marine limestone strata of the Amsden overlaps successively lower Amsden redbeds and the upper part of the Big Snowy group. The Ellis is a transgressive marine deposit. While it rests on a Jurassic evaporite series in the eastern part of the area, the Ellis also overlies the Amsden, each member of the Big Snowy group, and the Madison at other localities.

The regional diastrophic history as revealed by this stratigraphic study includes the following: post-Madison-pre-Big Snowy uplift, post-Big Snowy-pre-Amsden folding, middle Amsden movement, post-Amsden-pre-Gypsum Springs (lower Ellis) uplift, middle Upper Jurassic movement, Laramide folding, Tertiary uplift.

INTRODUCTION

The Judith Basin area of central Montana is a topographic and structural low bounded on the south by the Big Snowy and Little Belt mountains, on the east by the Judith, North and South Moccasin mountains, and on the west by the Highwood Mountains (Fig. 1). Although gently northeast-dipping beds of the Upper Cretaceous Colorado shale occupy most of the Judith Basin, continuous outcrops of steeply dipping older formations are present on the mountain flanks around the periphery of the Basin. The strata described are exposed solely along the margins of the Basin. These exposures and the available subsurface information furnish the data for this paper.

The strata with which this paper is concerned are the Carboniferous Big Snowy group and Amsden formation as defined in this area by Scott,[2a] and the Jurassic Ellis formation, first described in the area by Weed.[3] Later work by Perry and Sloss[4] has expanded the knowledge of the Carboniferous to a regional aspect. Cobban[5] extended his Sweetgrass arch detailed study of the Ellis into the

[1] Manuscript received, February 1, 1946. Published by permission of Pacific Western Oil Corporation.

[2] Division geologist, Rocky Mountain division, Pacific Western Oil Corporation.

[2a] H. W. Scott, "Some Carboniferous Stratigraphy in Montana and Northwestern Wyoming," *Jour. Geology*, Vol. 43 (1935), pp. 1011–32.

[3] W. H. Weed, "Two Montana Coal Fields," *Bull. Geol. Soc. America*, Vol. 33 (1892), p. 309.

[4] E. S. Perry and L. L. Sloss, "Big Snowy Group: Lithology and Correlation in the Northern Great Plains," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 27 (1943), No. 10, pp. 1287–1304.

[5] W. A. Cobban, "Marine Jurassic Formations of Sweetgrass Arch, Montana," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 29, No. 9 (September, 1945), pp. 1262–1303.

western edge of the Judith Basin. Gardner *et al.*[6] included a part of this area in the stratigraphic investigations which were carried on in central Montana.

PURPOSE

The purpose of the present work is two-fold: (1) to show the continuity and detailed correlation of some Jurassic and Carboniferous lithologic units of the

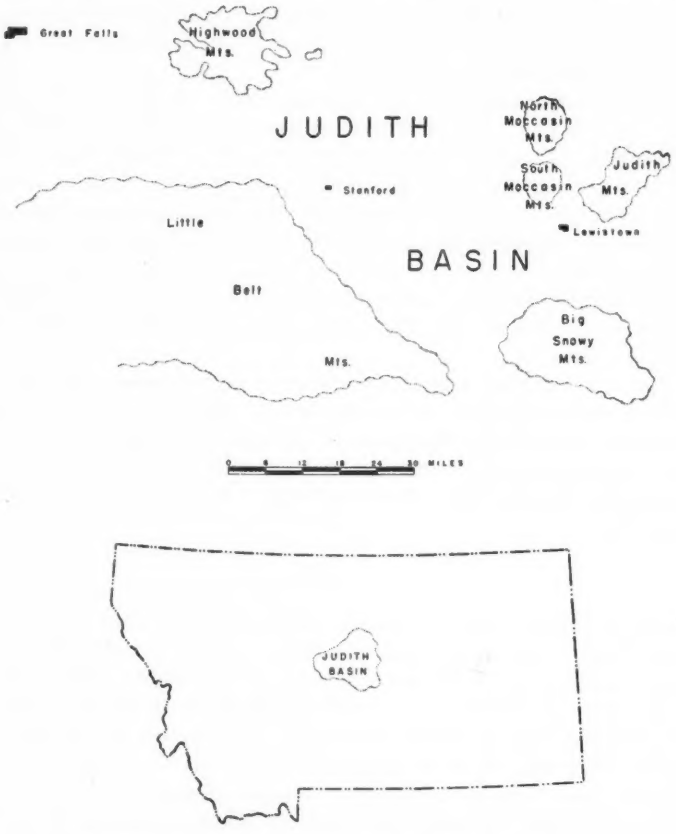


FIG. 1.—Geographical location, Judith Basin, Montana.

Judith Basin area; and (2) to demonstrate the relationship between the sedimentational units and certain diastrophic events that occurred in the area.

[6] L. S. Gardner *et al.* "Columnar Sections of Mesozoic and Paleozoic Rocks in the Mountains of South-Central Montana," *U. S. Geol. Survey Oil and Gas Investigations Preliminary Chart 18.*

STRATIGRAPHY

DEFINITION

The Big Snowy group, named and assigned to the middle and upper Mississippian by Scott,[7] consists of the Kibbey, Otter, and Heath in depositional order, each of which is a distinct lithologic unit readily recognized on an outcrop section or in well cuttings in the Judith Basin area. A sequence of beds lying between the Kibbey and the middle Mississippian Madison limestone is known only from well information, but was included in the Big Snowy group by Seager[8] as the Charles formation.

The distinctive sequence of beds unconformably overlying and truncating locally the Big Snowy group, herein called Amsden, contain a macrofauna that was assigned to the upper Mississippian (Chester) by Scott.[9] Later work by Scott,[10] however, has revealed Pennsylvanian (Morrow) fusilinids to be present in the lower Amsden and this latter age determination is accepted herein.

The Jurassic Ellis formation overlies the Amsden disconformably throughout the southern part of the area described. Pre-Jurassic erosion has removed successively the Amsden and Big Snowy group so that progressively northward the Ellis overlaps the Amsden and Big Snowy group until it lies disconformably on the Madison limestone.

Overlying the marine Ellis is a sequence of heterogeneous continental and brackish-water beds properly called the Jurassic Morrison formation. The contact between the Ellis and Morrison, as determined by the writer, represents mainly a depositional break, that is, an apparently abrupt change in type of sedimentation. Whether this contact represents a true time line or not is highly problematical.

LITHOLOGIC CHARACTER AND CORRELATION

BIG SNOWY GROUP

Charles formation.—The sample log of The California Company's Romundstad well No. 1 in the Armells gas field shows 140 feet of red shales and white limestones underlying typical red sandstone of the Kibbey formation which rests on white dense limestone, probably the Madison. These have been tentatively correlated with the Charles formation. These strata are the only beds in the Judith Basin area which by either outcrop sections or subsurface data might be properly called Charles, as defined by Seager[11] (Fig. 4).

Kibbey formation.—In outcrop sections the Kibbey formation is represented by a changeable lithologic character. Though it everywhere contains some beds

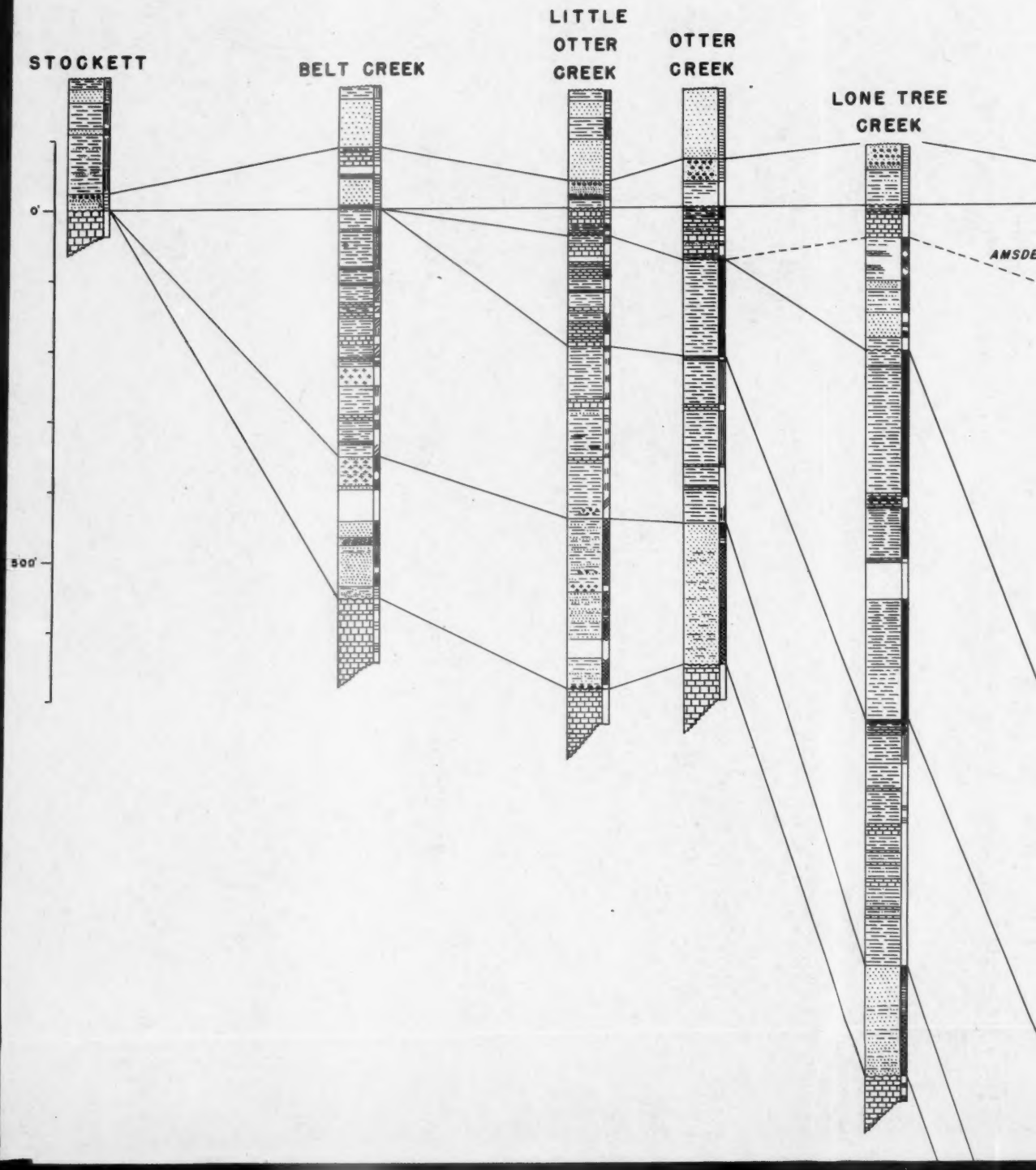
[7] H. W. Scott, *op. cit.*, pp. 1011–32.

[8] O. A. Seager, "Test on Cedar Creek Anticline, Southeastern Montana," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 26 (1942), p. 864.

[9] H. W. Scott, *op. cit.*, pp. 1022–23.

[10] H. W. Scott, personal communication, March 18, 1946.

[11] O. A. Seager, *op. cit.*, p. 864.


STOCKETT
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LITTLE OTTER CREEK
OTTER CREEK
LONE TREE CREEK
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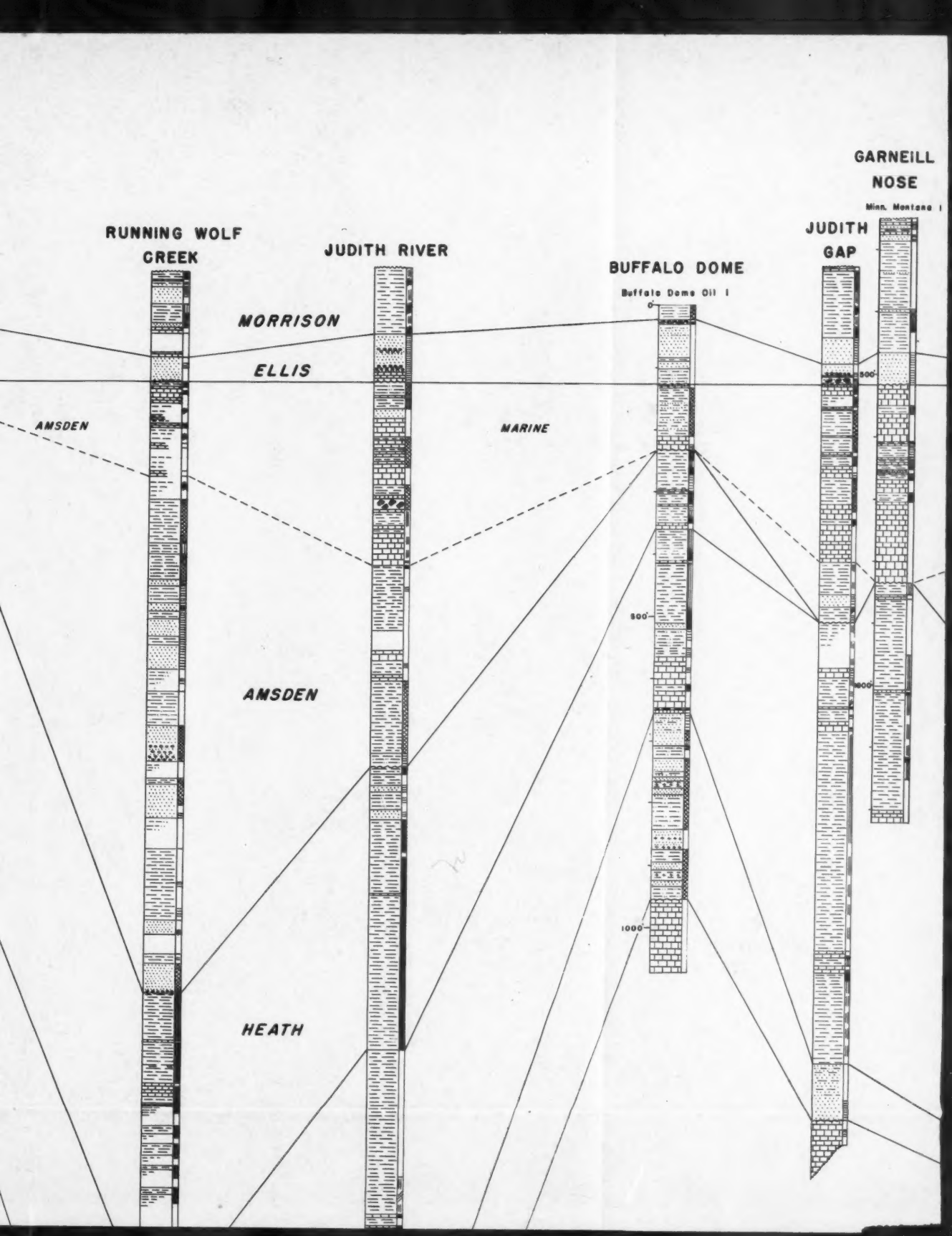
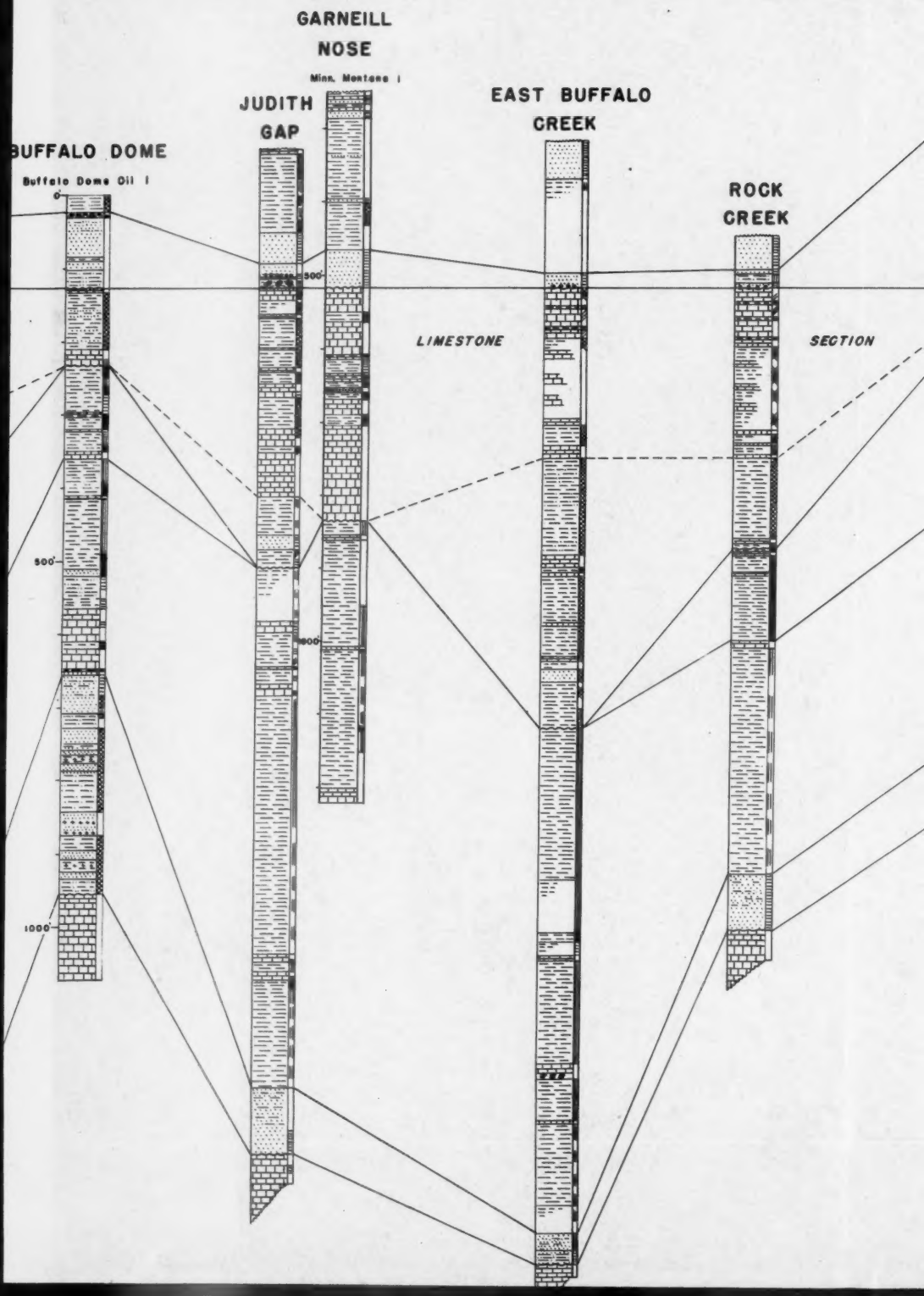
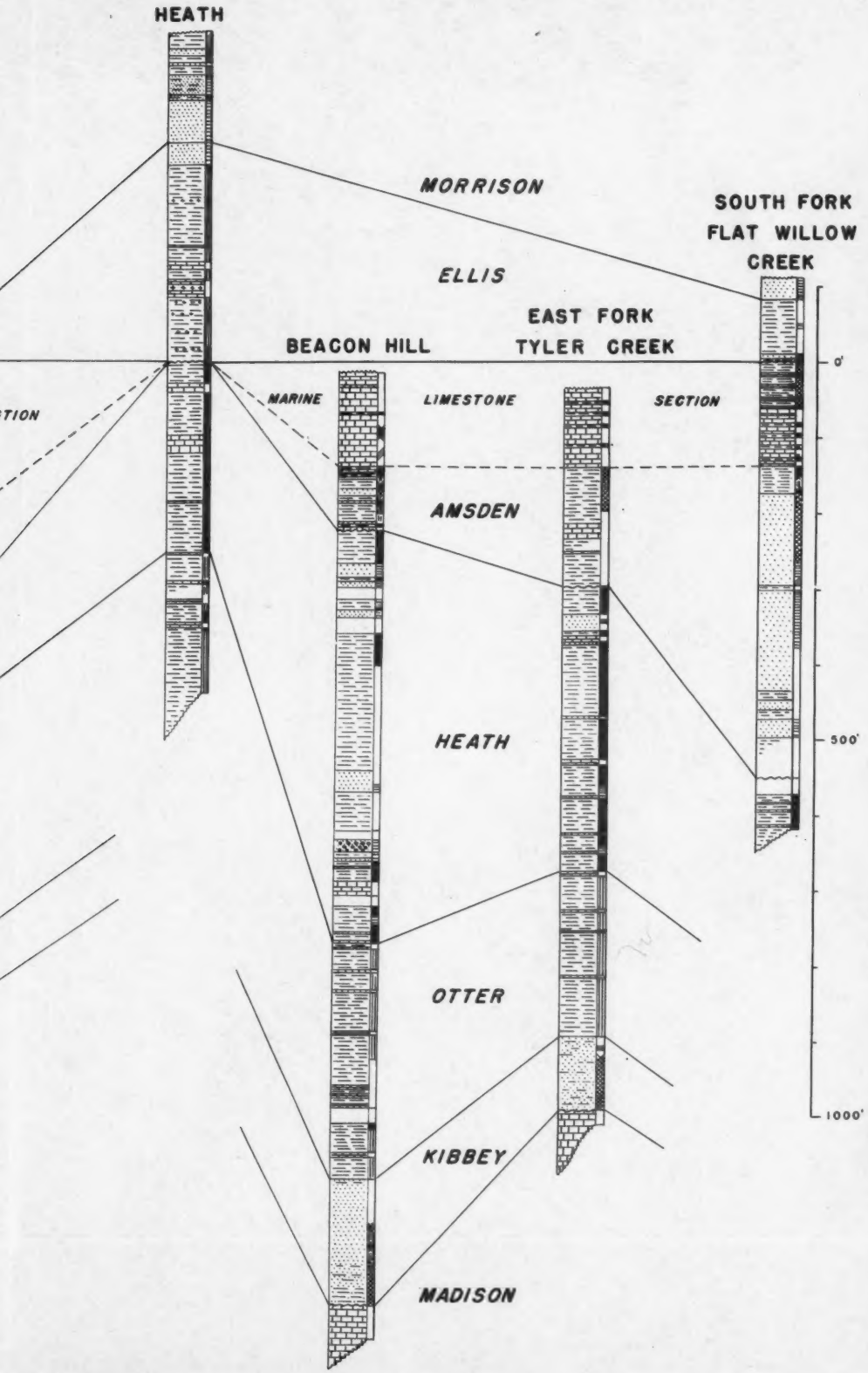
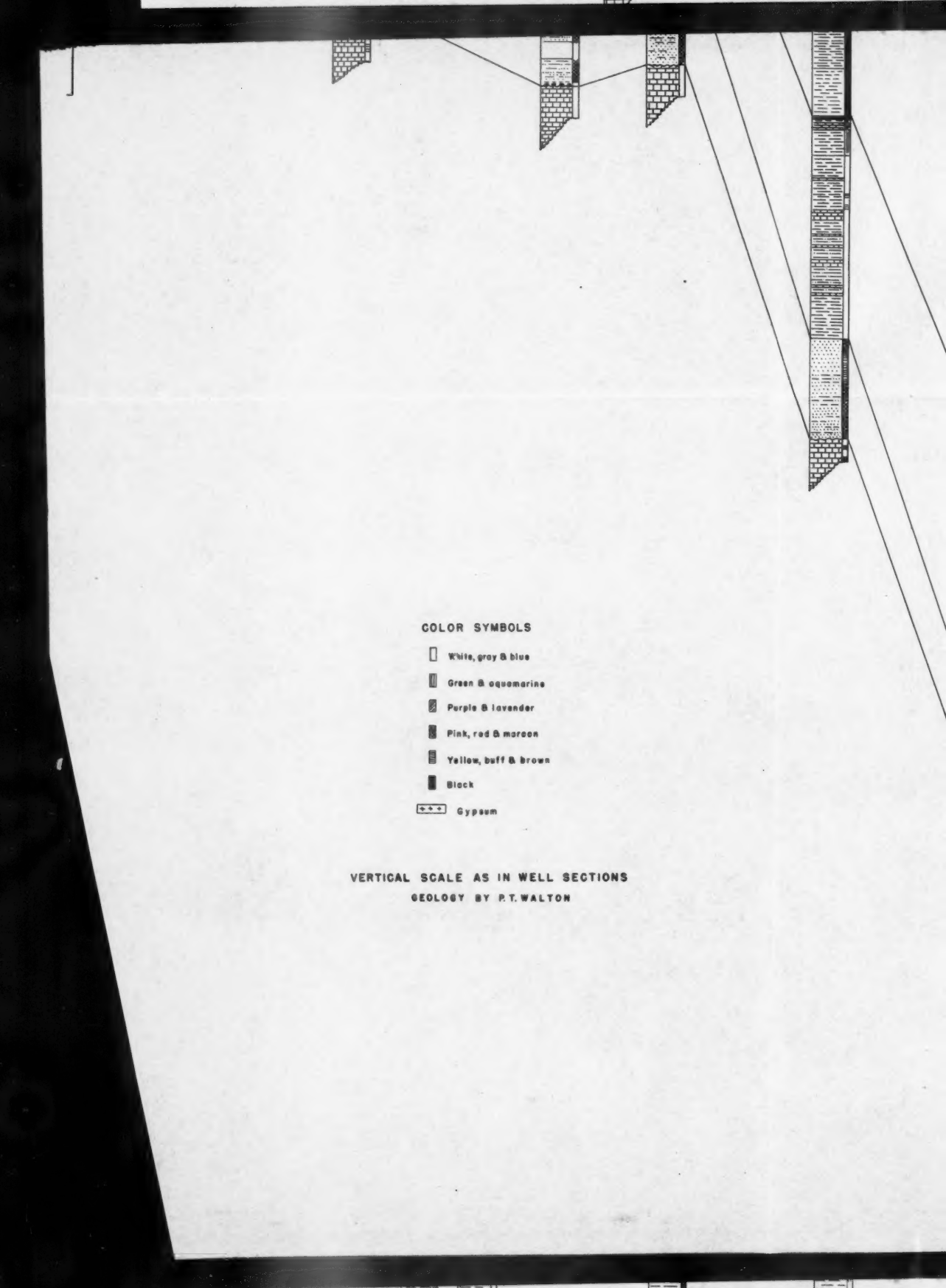

RUNNING WOLF CREEK
JUDITH RIVER
BUFFALO DOME
Buffalo Dome Oil 1
JUDITH GAP
GARNEILL NOSE
Minn. Montana 1
MORRISON
ELLIS
AMSDEN
MARINE
AMSDEN
HEATH
0'
500'
500'
500'
1000'


GARNEILL
NOSE
Minn. Montana 1
JUDITH
GAP
EAST BUFFALO
CREEK
BUFFALO DOME
Buffalo Dome Oil 1
ROCK
CREEK
0'
500'
500'
500'
1000'
LIMESTONE
SECTION


HEATH
MORRISON
SOUTH FORK
FLAT WILLOW
CREEK
ELLIS
EAST FORK
TYLER CREEK
BEACON HILL
MARINE
LIMESTONE
SECTION
0'
AMSDEN
HEATH
500'
OTTER
KIBBEY
1000'
MADISON



COLOR SYMBOLS

- White, gray & blue
- Green & aquamarine
- Purple & lavender
- Pink, red & maroon
- Yellow, buff & brown
- Black
- Gypsum

VERTICAL SCALE AS IN WELL SECTIONS

GEOLOGY BY P.T. WALTON

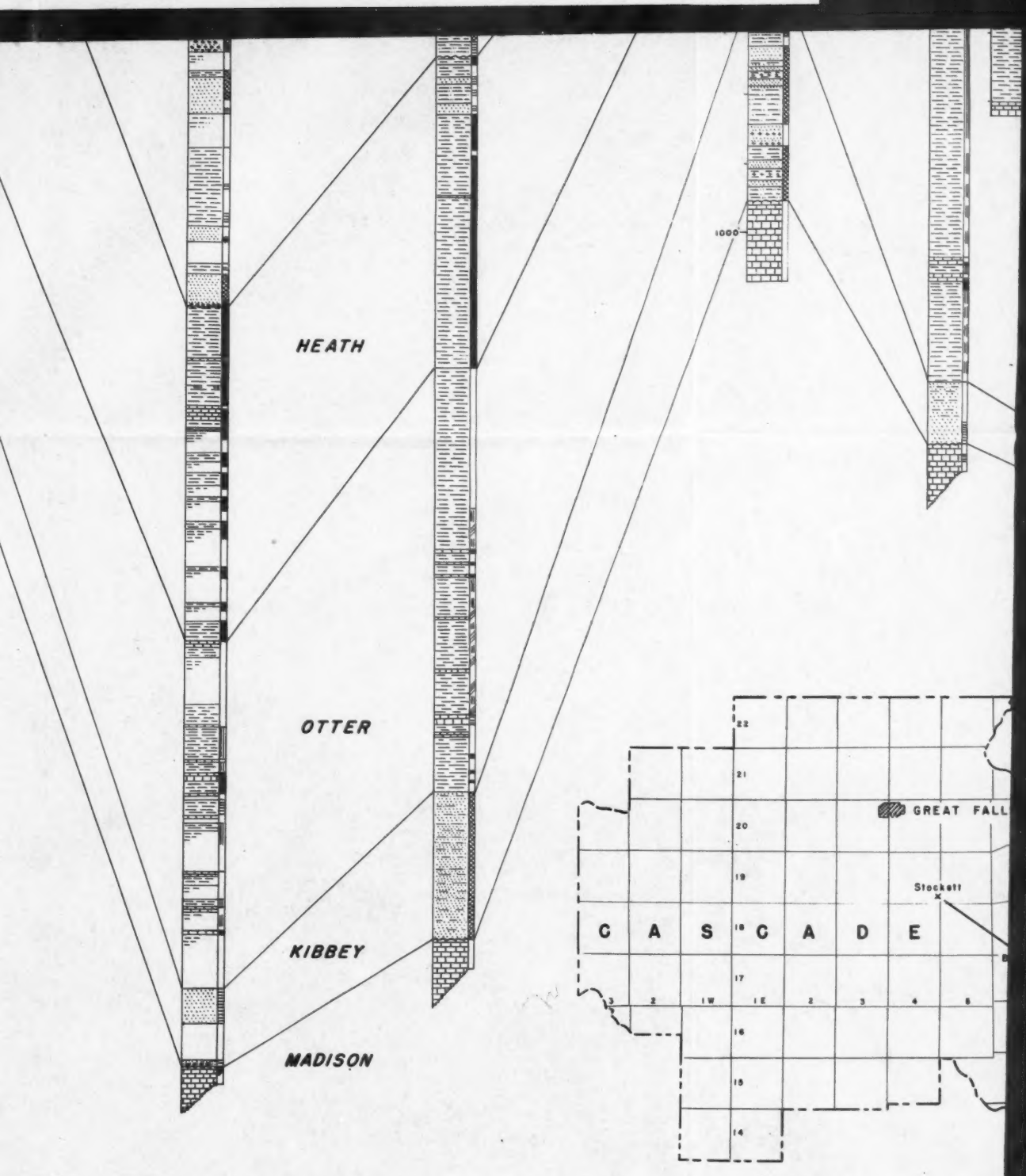
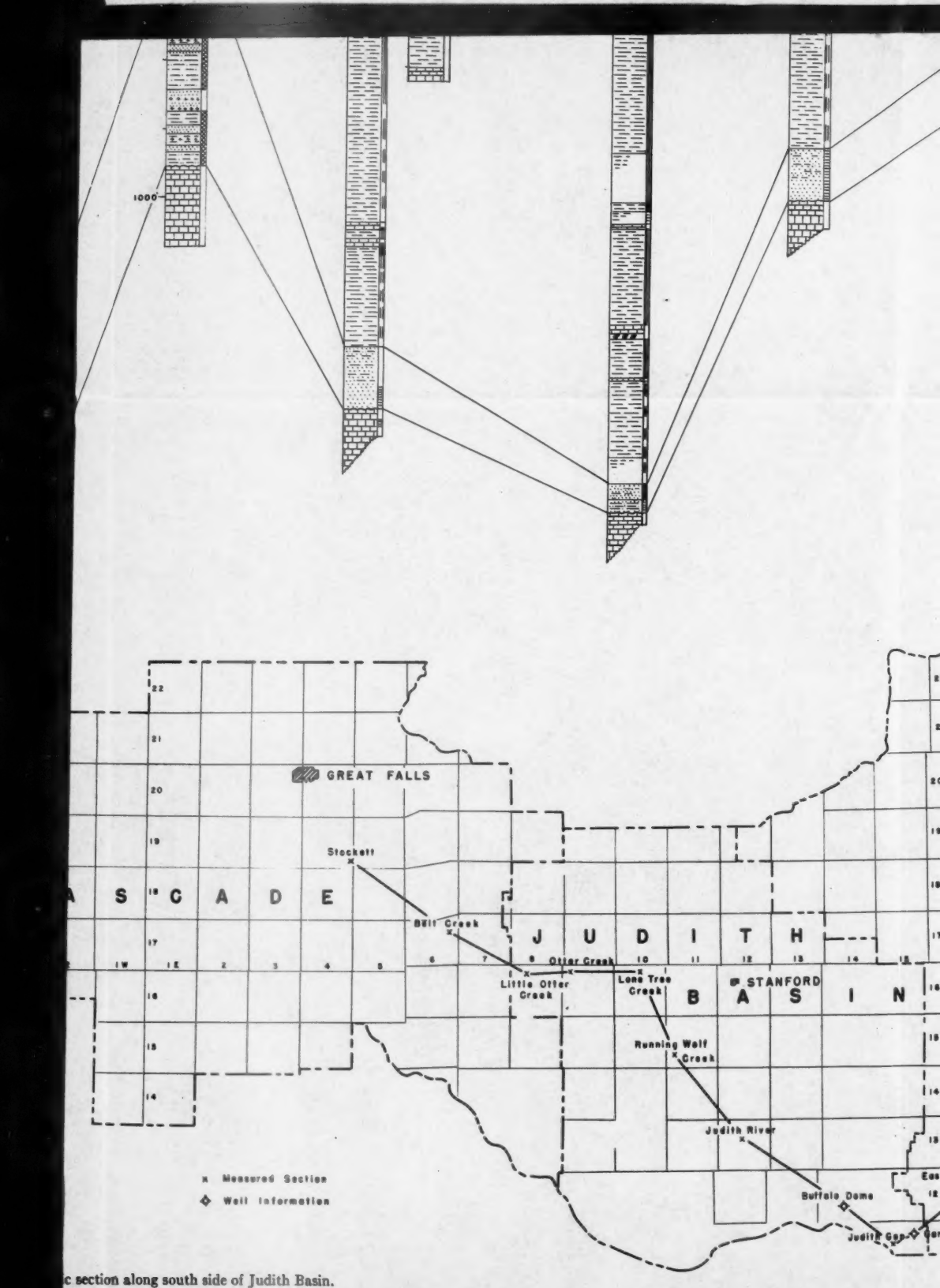
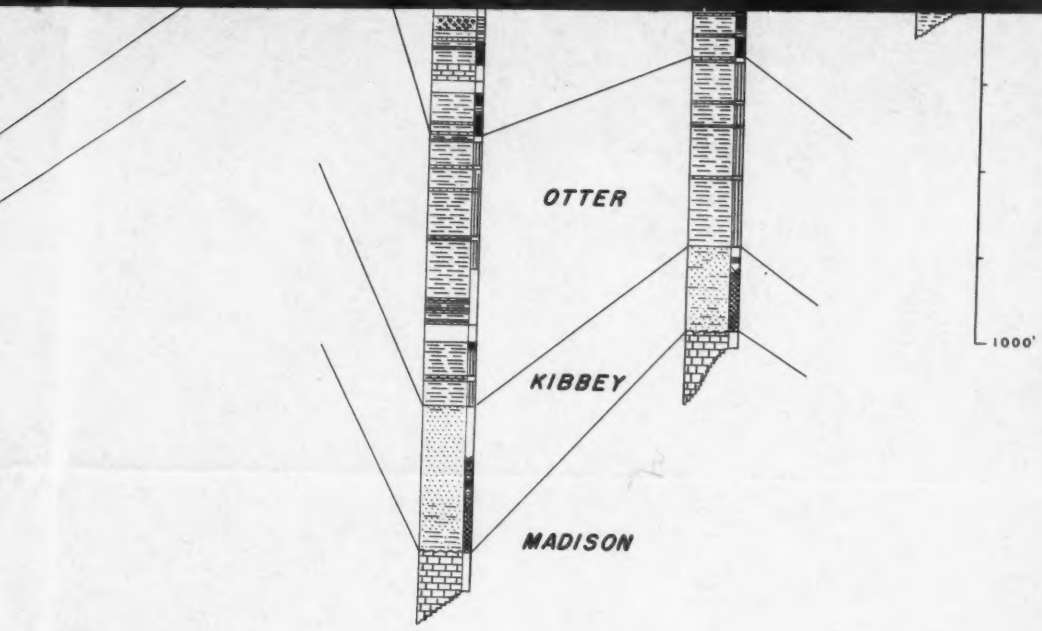
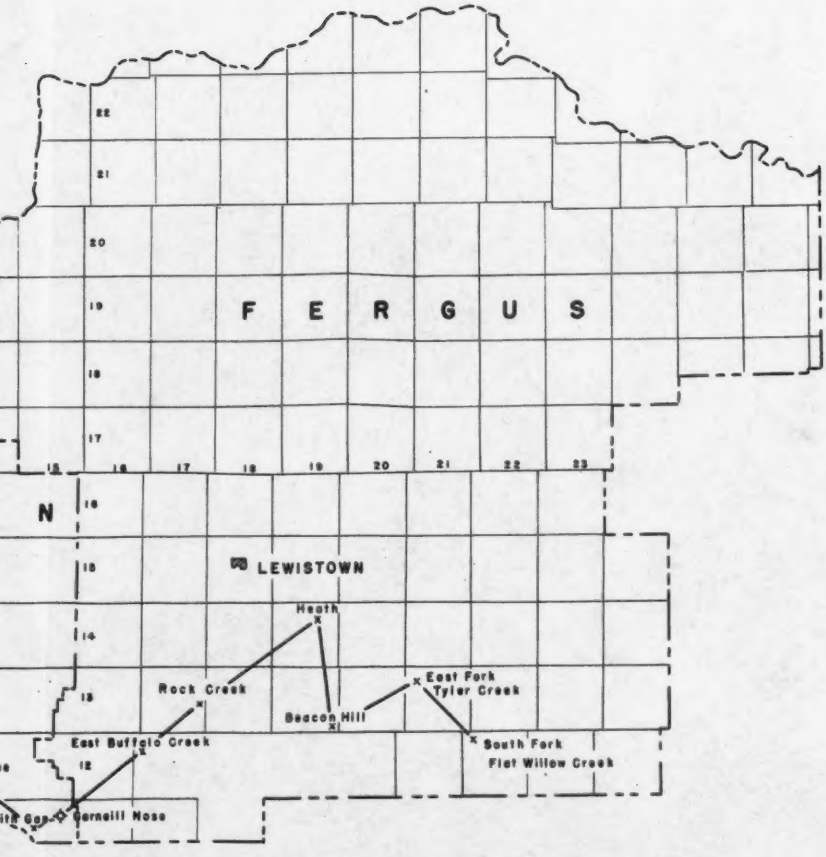


FIG. 2.—West-east stratigraphic section along south side of Judith Basin.



c section along south side of Judith Basin.


OTTER
KIBBEY
MADISON
1000'


F E R G U S
LEWISTOWN
Heath
Rock Creek
Beacon Hill
East Fork
Tyler Creek
East Buffalo Creek
South Fork
Flat Willow Creek
Cornell Nose
N

of pink or red silty sandstone, commonly it contains other constituents. In the Belt Creek and Little Otter Creek sections, as well as in the Buffalo Dome well (Fig. 2) many beds of red shale and white gypsum are present. At Rock Creek and Judith Gap the Kibbey is clean, white to buff, porous, soft sand, capable of of being an excellent aquifer or reservoir for oil. Its maximum observed thickness of 305 feet is in the Buffalo Dome well, and it thins to less than 50 feet at East Buffalo Creek.

At the western side of the Basin adjacent to the Sweetgrass arch and along the northeastern margin of the Judith Basin near the North Moccasin Mountains, the Kibbey sandstones are composed of finer-grained particles and contain more silt than elsewhere observed. Moreover, the Kibbey in the same areas contains more limestone and gypsum beds than at other localities. These data imply that the Kibbey had its source south of the Judith Basin. The sections immediately east of the Sweetgrass arch indicate the presence of a local "deep," because the Kibbey is not only thick and finer-grained there, but also contains the most evaporite beds of any area studied. Though no fossils have been found in the Kibbey, its general lithologic character and distribution indicate it was deposited in a huge flood plain adjacent to an estuarine environment where occasional local barred basins fostered evaporite deposition. An oxidizing climate, probably semi-tropical, seems indicated by the persistent red color of the Kibbey. The glazed and silicified character of the underlying Madison limestone, combined with the presence of pre-Kibbey sink holes, such as those along Belt Creek near Riceville, appear as positive evidence for the presence of widespread sub-aerial erosion prior to Kibbey time.

Otter formation.—In outcrop sections the Otter formation commonly consists of aquamarine shale interbedded with light greenish gray and gray shale, and gray dense limestone. Thin beds of black fissile shale and black fetid limestone, typical of the overlying Heath formation, occur intermittently throughout the Otter section, though none can be traced far laterally. These apparently represent local deposition where conditions existed for short periods identical with those during Heath time.

Nearer the western margin of the Judith Basin, on the east flank of the Sweetgrass arch, the Otter formation has a varied lithologic character. While containing typical vivid green and gray shale, many beds of lavender siltstone are present, and along Belt Creek, a large massive bed of white gypsum is present (Fig. 2).

On the extreme eastern edge of the Basin in The California Company's State well No. 1, a series of red and green shale, buff sandstone, and white limestone lies below definite Heath shale. These beds have been assigned to the Otter with reservation, and only because of their stratigraphic position. Probably they represent the time equivalents of Otter, if not the same lithologic unit (Fig. 4).

Both the upper and lower boundaries of the Otter are placed at lithologic

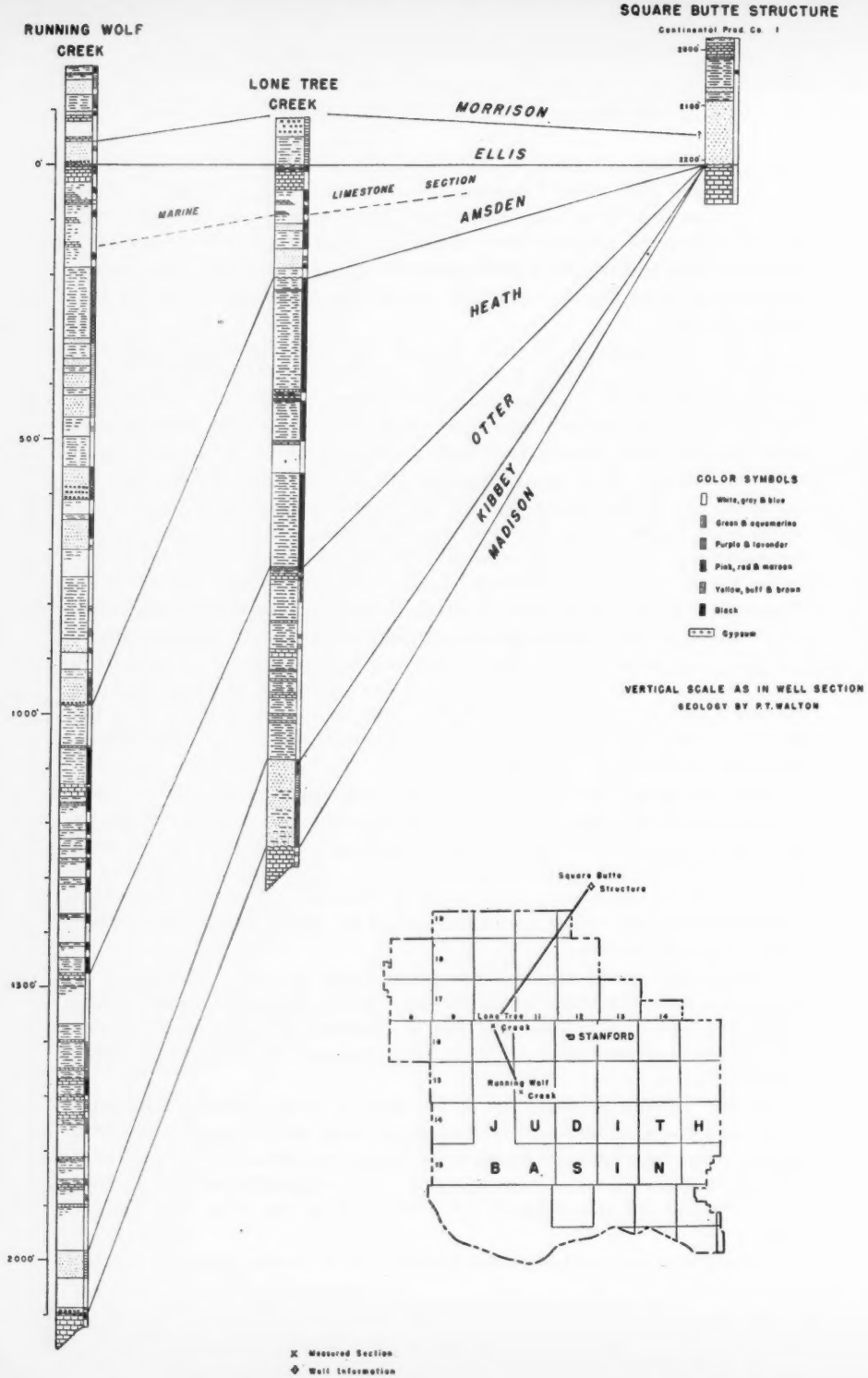


FIG. 3.—South-north stratigraphic section on west side of Judith Basin.

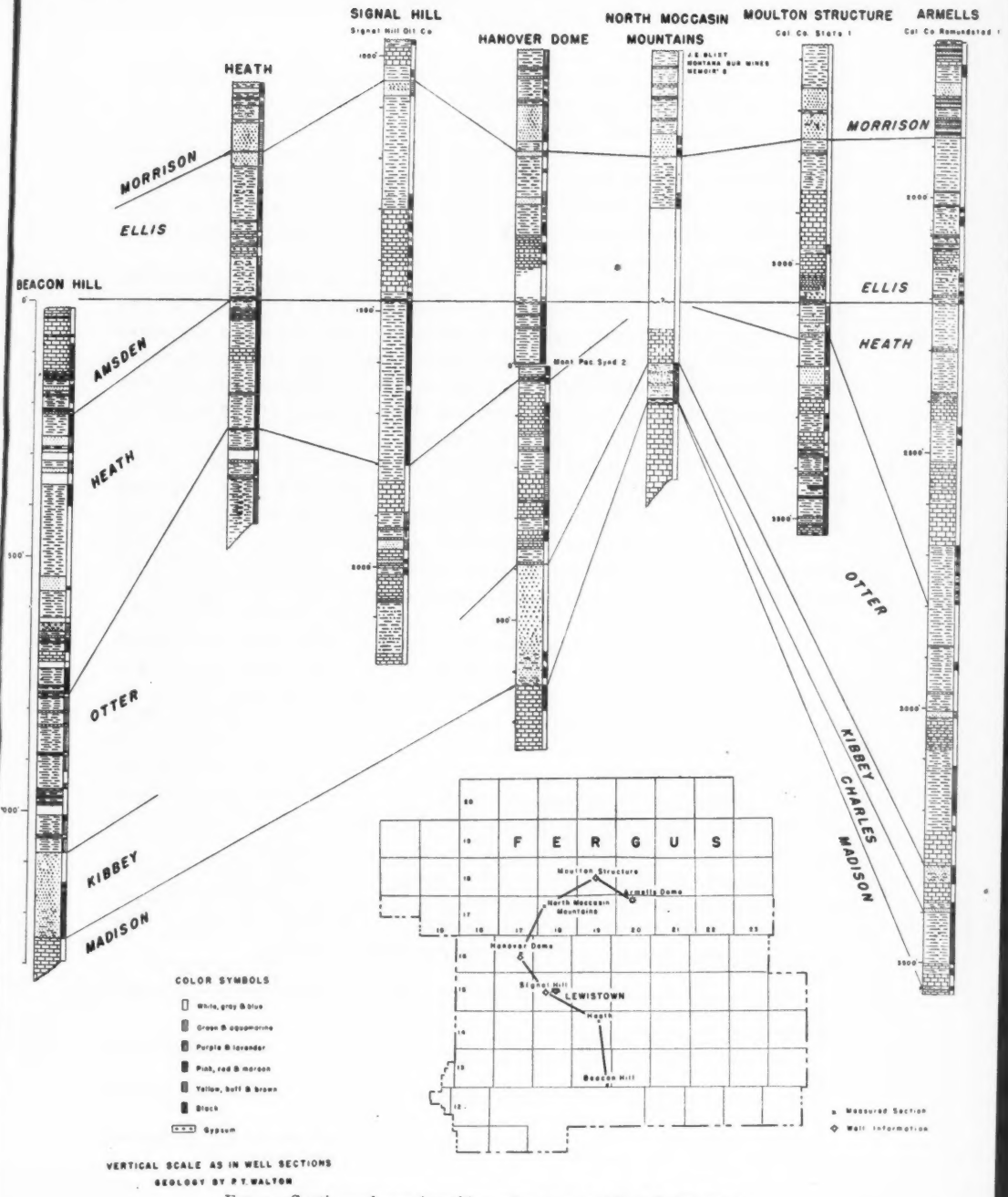


FIG. 4.—South-north stratigraphic section on east side of Judith Basin.

changes. Unquestionably the contacts between the Otter and underlying Kibbey, and the overlying Heath are gradational and transect time lines.

As suggested by Scott,[12] the green coloration of the Otter is due to ferrous iron. Probably the present shades of the Otter, trending from aquamarine to lavender and gray, are an index to the magnitude of the reducing processes going on during the deposition of these beds. The fossil assemblages gathered by Scott[13] clearly indicate a marine environment. The color criteria imply deposition in a near-shore environment where some organic material existed.

Little can be said of the source of the sediment for the Otter except that the thickness of the limestones, gypsum, and lavender shales appears to become greater toward the southwest and west. Whether this represents a local deepening of the sea of deposition, or merely a local estuarine environment, is questionable. The only parallel evidence is that the Otter beds in the Moulton structure well in the extreme northeastern part of the area (Fig. 4) contain coarse sandstones and red shales, indicating a nearer-shore deposit.

Heath formation.—The Heath formation consists of a body of black, calcareous, fissile shale containing beds of dark blue and gray clay shale, and black fetid, dense limestones. In places, beds of buff, coarse sandstone up to 30 feet in thickness are present in the upper third of the formation. At Beacon Hill (Fig. 2), a conglomeratic sandstone occurs near the base of the Heath. Freeman[14] called the upper sands the Tyler, from their exposure near that town, but because of their great lenticularity they can not be traced far from this locality.

Perry and Sloss[15] noted a progressive decrease in grain size of these Heath sands toward eastern Montana. These sands appear to be coarsest and thickest in the Judith Basin area in the Beacon Hill and Judith River districts (Fig. 2), and are absent farther west by non-deposition in the Lone Tree-Running Wolf area. The inference is that the source of the sand is south or southwest rather than in the Sweetgrass arch. Likewise the Heath contains more limestone immediately east of the Sweetgrass arch in the Little Otter Creek section than at any other area. Again the evidence points toward a local "deep" there, such as may have been present during deposition of the Kibbey and Otter.

The Heath's lower boundary is based solely on lithologic character and is taken at the contact between the lowest black shale bed of appreciable thickness and the aquamarine, gray, or grayish green shale of the Otter. As already mentioned, this contact undoubtedly does not represent a time line.

[12] H. W. Scott, "Some Carboniferous Stratigraphy in Montana and Northwestern Wyoming," *Jour. Geology*, Vol. 43 (1935), p. 1027.

[13] H. W. Scott, *op. cit.*, p. 1028.
———, "Ostracodes from the Upper Mississippian of Montana," *Jour. Paleon.*, Vol. 16 (1942), p. 152.

[14] O. W. Freeman, "Oil in the Quadrant Formation in Montana," *Eng. and Min. Jour.*, Vol. 113 (1922), p. 827.

[15] E. S. Perry and L. L. Sloss, "Big Snowy Group: Lithology and Correlation in the Northern Great Plains," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 27, No. 10 (October, 1943), p. 1298.

The upper boundary of the Heath is an unconformity. Pre-Amsden erosion has removed the Heath entirely in the area near Judith Gap, for the Amsden there lies on the Otter (Fig. 2). From the vicinity of Heath northward, pre-Ellis erosion has removed all of the Amsden and much of the Heath shale (Fig. 4). In this area the gypsiferous beds of the lower Ellis lie on the Heath. On the east flank of the Sweetgrass arch, along Belt Creek, all of the Heath is eroded away and the Ellis lies on the Otter. The greatest thickness of Heath occurs in the Judith River-Running Wolf area where a local downwarp occurred during deposition of the lower Amsden. The top of the Heath was probably eroded very little in this local "low" so that the original thickness of the Heath is present. Elsewhere only eroded remnants remain.

The black Heath shale contains débris of both marine and brackish-water organisms. Scott[16] has described the marine fauna. Many of the outcrop sections studied by the writer contain coal beds only a fraction of an inch thick. Several of the Heath sandstones contain unidentified woody plant fragments, notably at Beacon Hill and Judith River.

Twenhofel[17] has ascribed the deposition of black shales mainly to quiet waters where bacterial action is stagnated and circulation of overlying water is absent, thus allowing the débris to accumulate from the abundant but specialized organisms present in an environment where oxygen is limited. In the case of the Heath, this sedimentational sequence was broken intermittently by influxes of marine flood waters which deposited blue and gray clay that later became the thin blue and gray shales present in many of the sections. Strong, near-shore currents carrying coarse material probably formed the scattered sand lenses.

Amsden.—The question of proper nomenclature of the beds herein called Amsden was well discussed by Perry and Sloss.[18] Their suggestion to retain the name Amsden for this lithologic unit even though it apparently contains both a Pennsylvanian and Mississippian fauna is followed herein.

Everywhere observed in the Judith Basin area, the Amsden consists of two distinctive members: (1) a lower sequence consisting of red and pink shales and mudstones, red, coarse, poorly sorted, ferruginous sandstones, and here and there thin beds of grayish green and buff, fine-grained limestone; (2) an upper sequence of marine, fossiliferous limestone containing interbedded red, maroon and purple shale. In places, where pre-Ellis erosion has not cut too deep, a thin sequence of yellow, pink and purple clay shale lies above the marine limestone section.

The base of the Amsden lies on an erosional surface truncating the Heath and Otter shales. The upper boundary is marked by the base of the Jurassic Ellis

[16] H. W. Scott, "Some Carboniferous Stratigraphy in Montana and Northwestern Wyoming," *Jour. Geology*, Vol. 43 (1935), p. 1029.

[17] W. H. Twenhofel, "Environments of Origin of Black Shales," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23, No. 8 (August, 1939), pp. 1185–97.

[18] E. S. Perry and L. L. Sloss, "Big Snowy Group: Lithology and Correlation in the Northern Great Plains," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 27, No. 10 (October, 1943), pp. 1293–95.

formation which truncates and overlaps all the Carboniferous formations in this area.

Pre-marine Amsden downwarping in the Judith River-Running Wolf area has accounted for a considerable thickness (835 feet) of red mudstones and red, highly ferruginous, coarse sandstones, and conglomeratic sand (Fig. 2).

Another downwarp in the vicinity of Flatwillow Creek on the extreme southeastern end of the Big Snowy Mountains is represented by a similar lithologic sequence. Surface exposures and sparse subsurface data near the Running Wolf section indicate that these beds were deposited in a northeast-southwest-trending "low." The possibility of a northward extension of this trough for any great distance seems small since the Square Butte well found Ellis resting on Madison (Fig. 3). Apparently the source of these redbeds was at the southwest, possibly from landmasses where the "ancestral" Sweetgrass arch crossed the main axis of the Little Belt Mountains. The source of the Amsden redbeds in the Flatwillow area is unknown, but probably they have the same origin, for their lithologic character is similar.

The Amsden marine limestone section apparently represents a transgressive overlapping marine deposit, for it lies not only on the lower Amsden redbeds, but also on members of the Big Snowy group at various outcrop sections and in several wells (Fig. 2). The thickness of this marine limestone section depends on two factors: (1) irregularity of the surface on which it was deposited; (2) amount of pre-Ellis erosion. Thicknesses of this limestone sequence vary from 40 feet at Little Otter Creek to 320 feet in the Garneill Nose well.

Ellis formation.—Throughout the area the Jurassic Ellis represents a transgressive marine deposit laid down on a surface of low relief. Cobban[19] divided the Ellis in the Sweetgrass arch region into three lithologic units, the Swift, Rierdon, and Sawtooth, in descending order. The Swift sandstone lies on the Madison limestone on the crest of the Sweetgrass arch at Stockett. Proceeding from this locality eastward into the Judith Basin some member of the Ellis rests successively on younger and younger beds in the following order: Kibbey, Otter, Heath, and Amsden until at Heath the Ellis rests on a Jurassic evaporite sequence (Fig. 2). Included herein as Ellis, this evaporite sequence is an estuarine deposit of gypsum, limestone, and red and green shale that lies disconformably on the black Heath shale at the U. S. Gypsum Plant at Heath. From some poorly preserved oysters which the writer collected from both above and below the main gypsum bed at this locality, Reeside[20] identified the following and referred them to the Jurassic.

Ostrea strigilecula White, cf. *Artica cinnabarensis* (Stanton)
Ostrea strigilecula White, cf. *Astarte meeki* Stanton, cf. *Artica cinnabarensis* (Stanton)

[19] W. A. Cobban, "Marine Jurassic Formations of Sweetgrass Arch, Montana," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 29, No. 9 (September, 1945), pp. 1262–1303.

[20] J. B. Reeside, Jr., personal communication.

Imlay[21] logically correlates these gypsum-bearing red shales and limestones of the Ellis with the Gypsum Springs formation of Wyoming which has similar lithologic character and age. In the Judith Basin area these evaporite beds were apparently deposited in a north-south-trending trough since they can not be traced farther west or northwest, but occur in both outcrops, and wells north and northeast from Heath (Fig. 4). The source of these sediments was probably at the west where, during the lower and middle Jurassic, erosion was occurring along the east flank of the Sweetgrass arch. As both the Kibbey and the Otter contain gypsum in the vicinity of the Sweetgrass arch, perhaps their erosional products were the source.

Although the field work for this report was completed before publication of Cobban's[22] report, nevertheless, in most outcrop sections shown herein, his tripartite divisions of the Ellis can be recognized, at least in part. In particular, the *Gryphaea*- and *Belemnites*-bearing conglomeratic sandstone that has such widespread occurrence in the area is directly correlative with the Swift. Certainly the buff to olive-drab fossiliferous shales and limestones found here and there below the Swift represent either Rierdon or Sawtooth equivalents, or both.

In most outcrop sections the lower boundary of the Ellis is easily found since it is marked by a profound unconformity. Moreover, the basal beds occasionally contain reworked pebbles of the underlying strata. The boundary between the overlying Morrison and the Ellis, however, is open to question in many outcrop sections and in most wells. In places, the buff conglomeratic sandstone herein correlated with Cobban's[23] Swift, grades upward imperceptibly into a brown, coarse, poorly sorted, fluvial type of sandstone. The top of the Ellis in these instances is placed at the top of the fossiliferous zone where an apparent sedimentational break occurred. It is doubtful if this depositional change represents a time line.

REGIONAL DIASTROPHIC HISTORY

This stratigraphic study has revealed the main diastrophic events that have occurred in the Judith Basin area since middle Mississippian time. Being of greater magnitude, the Laramide revolution and subsequent Tertiary uplifts have greatly obscured older diastrophism; therefore, the stratigraphic sections have been purposely drawn on the base of the Ellis as a level line in an attempt to show pre-Laramide structure. The structural "highs" and "lows" thus shown in the pre-Jurassic formations represent the final resolution of all diastrophic, erosional and sedimentational events preceding deposition of the Ellis. The more important and most evident periods of earth movement that have occurred during and subsequent to the deposition of the strata herein described are as follows.

[21] Ralph W. Imlay, "Occurrence of Middle Jurassic Rocks in Western Interior of United States," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 29, No. 7 (July, 1945), pp. 1023–25.

[22] W. A. Cobban, *op. cit.*

[23] W. A. Cobban, *op. cit.*, p. 1281.

Post-Madison-pre-Big Snowy uplift.—The regional disconformity between the Madison limestone and the base of the Big Snowy group is the result of a large-scale uplift in which much of the region was raised above sea-level so that the surface of the limestone was peneplaned. The Charles and Kibbey were deposited on that surface. The region remained near or below sea-level during Big Snowy time.

Post-Big Snowy-pre-Amsden folding.—Following deposition of the Heath, the region was uplifted above sea-level and a series of low north-south-trending folds was formed. This was probably the first movement on the ancestral Sweetgrass arch as it was then uplifted so that at least a part of the Heath and probably some of the Otter were eroded from its top. In the syncline formed near the Running Wolf-Judith River area, a considerable thickness of red, coarse, lower Amsden sands and shales was deposited. Two other arches were formed: one at Judith Gap, where erosion removed the Heath, and the other between Rock Creek and Heath, where only a part of the Heath was stripped away. In the syncline at Flat Willow Creek more red sands and shales were deposited.

Middle Amsden movement.—Following deposition of the lower Amsden redbeds, the whole region was lowered below sea-level. The marine limestones thus deposited transgressed all the previously formed folds, overlapping the Amsden redbeds, which is the case at Otter and Little Otter creeks, where the marine Amsden clearly overlaps the lower redbed section. Probably all of the southern part of the Sweetgrass arch was covered by these marine Amsden limestones.

Post-Amsden-pre-Gypsum Springs uplift.—During the long period of time between the Lower Pennsylvanian and Middle Jurassic, represented by the hiatus between the Ellis and the Amsden, an uplift, epeirogenic in size, occurred. Rejuvenation occurred along the Sweetgrass arch and the marine Amsden, the whole Big Snowy group, and some of the Madison were stripped from its crest by erosion. Regional tilting to the south made it possible for erosion to strip all the Amsden, Big Snowy, and some Madison from the north end of the Judith Basin area (Fig. 3). In the area northeast of the Judith Basin the Amsden was removed but most of the Big Snowy group remained. As the region again submerged, the Gypsum Springs equivalents were deposited in a near-sea-level estuarine environment in a broad north-south trough.

Middle Upper Jurassic movement.—At the beginning of Ellis time the area was submerged and marine deposition occurred. Since the Swift, Cobban's[24] uppermost member of the Ellis, lies on the Madison limestone at Stockett, rejuvenation of the Sweetgrass arch during middle Upper Jurassic is indicated. Farther east at Running Wolf Creek and in outcrop sections and wells between Judith Gap and East Buffalo Creek, conglomeratic Swift beds rest on the Amsden (Fig. 2). Elsewhere along the north flank of the Little Belt and Big Snowy mountains, the Swift overlies beds unquestionably equivalent to the Rierdon

[24] W. A. Cobban, *op. cit.*

and Sawtooth. Pre-Swift local folding, erosion and re-submergence at each of the localities aforenamed is clearly evident.

Post-Morrison-pre-Kootenai movement.—Typical Morrison is known to be present throughout much of the Judith Basin area and even on the crest of the Sweetgrass arch at the west. Cobban[25] noted pre-Kootenai (Lower Cretaceous) movement and erosion of all the Morrison and Swift from the vicinity of the Cutbank oil field. Probably if more subsurface data were available in the Judith Basin, a similar condition might be found.

Laramide folding and Tertiary uplift.—Near the close of the Upper Cretaceous, intense regional orogenesis began and probably continued well into the Tertiary. During this epoch the ancestral Sweetgrass arch was rejuvenated, assuming its present attitude and form. Contemporaneously the Little Belts, North and South Moccasins, Judith, and Big Snowy mountains were folded, intruded and uplifted. In all except the Big Snowies, dioritic plugs are now exposed by erosion. Late Tertiary extrusions of rhyolite lava formed the Highwood Mountains, the present northwest boundary of the Judith Basin.

[25] W. A. Cobban, *op. cit.*, pp. 1290–91.

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GEOLOGICAL NOTES

RACCOON BEND SALT DOME, AUSTIN COUNTY, TEXAS[1]

H. J. McLELLAN[2]
Houston, Texas

The Raccoon Bend field, located about 60 miles northwest of Houston in the northwest corner of Austin County, Texas, was discovered in 1928. A paper[3] published in 1933 described the structure as a broad faulted dome having an uplift on the Jackson formation in excess of 800 feet.

The early oil production was from two sands in the Jackson at depths of approximately 3,150 and 3,475 feet. In 1934, production was established from a sand in the upper Yegua formation at a depth of 4,100 feet. As of January 1, 1946, the cumulative production was about 15,500,000 barrels from the Yegua and about 19,700,000 barrels from the Jackson. The average daily production on that date was approximately 7,100 barrels from the Yegua and 1,100 barrels from the Jackson.

This structure was proved to be a salt dome in May, 1946, when the Humble Oil and Refining Company's L. R. Sherrod Y-16 was abandoned at the depth of 11,447 feet in salt. The section encountered below the top of the Jackson, as determined by samples and the electric log, was as follows.

	Depth in Feet
Jackson	2,900 – 3,900
Yegua	4,800
Crockett-Lower Claiborne	6,440
Wilcox	11,110
Midway	11,294
Cretaceous	11,400
Salt	11,447 (Total depth)

The thickness of the Wilcox formation is 4,670 feet, which is about 1,000 feet less than the estimated normal thickness for this area. On the electrical log the section below 9,426 feet is not typical of the Wilcox, being principally shale with some sections having high resistivity; however, the sample reports of this section show definite Wilcox lithology.

Most of the sands in the Wilcox appeared to have little permeability. The first porous sand was cored from 6,692 to 6,700 feet and had a good odor and stain of oil, but showed salt water with a small amount of gas on a drill-stem test. Side-wall cores, taken in the interval from 9,216 to 9,228 feet, had fair showings of oil but very low permeability, 0.2 to 1.2 millidarcys. The best showings of gas, as

[1] Manuscript received, June 20, 1946.

[2] Geologist, Humble Oil and Refining Company.

[3] L. P. Teas and Charis R. Miller, "Raccoon Bend Oil Field," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, No. 12 (December, 1933), pp. 1459–91.

recorded by the mud-logger, were in shale sections. At the depth of 11,018 feet, high pressure was encountered which resulted in a fishing job.

In a core cut at 11,437 to 11,447 feet the recovery was 5 feet of crystalline salt. The electrical log indicates the top of the salt at approximately 11,400 feet. Gray marl appeared in the cuttings at 11,320 feet, and a few fragments of cream-colored chalk appeared at 11,384 feet. Although fossils are rare, these samples are believed to be the equivalent in age of marl and chalk found in the cap rock of the South Liberty[4] and McFaddin Beach[5] salt domes.

Structurally, this well appears to be near the crest of the dome, being 307 feet higher on the Wilcox than the Humble's Woodley Y-17, located one mile southwest, and 481 feet higher than the Humble's Hardy Y-7, located 1½ miles northwest. The amount of uplift on the Wilcox on this dome is about 2,000 feet.

From the standpoint of geophysics, the finding of salt here was not surprising, since a large closed-gravity minimum anomaly is present. Also, this structure is well within the salt-dome belt, being 17 miles northwest of the Hockley dome, and 22 miles southeast of the Brenham dome.

This is the deepest salt found to date on a dome in Texas, the next deepest being at Clam Lake, Jefferson County, where salt was topped at 8,156 feet, and at Port Neches, Orange County, where salt was found at 7,206 feet. In Louisiana, the deepest proved dome is at Barataria, Jefferson Parish, where salt was topped at 12,608 feet. Other deep domes in Louisiana are Jeanerette, St. Mary Parish, top of salt 10,314 feet; and Octave Pass, Plaquemines Parish, top of salt 9,758 feet.

[4] T. E. Morrison, "First Authentic Cretaceous Formation Found on Gulf Coast Salt Domes of Texas," *ibid.*, Vol. 13, No. 8 (August, 1929), pp. 1065–69.

[5] E. P. Tatum, "Upper Cretaceous Chalk in Cap Rock of McFaddin Beach Salt Dome, Jefferson County, Texas," *ibid.*, Vol. 23, No. 3 (March, 1939), pp. 339–42.

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REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library, and are available, for loan, to members and associates.

THE WILDCATTERS, BY SAMUEL W. TAIT, JR.

REVIEW BY EDWARD A. KOESTER[1]
Wichita, Kansas

The Wildcatters, by Samuel W. Tait, Jr. 205 pages. Illustrated. Princeton University Press, Princeton, New Jersey (1946). Price, $3.00.

Here we have the story in a scant two hundred pages of the men who have made this country pre-eminent in the world of petroleum. It is told accurately, concisely and in a style that reads like the melodrama that the United States oil industry has been. The author was born in "the shadow of an oil derrick" and knows well the men and events which he describes. He traces the development of the oil industry from its birth along Oil Creek in Pennsylvania across the prairies and mountains to the Pacific coast and down to the Gulf. He catches the spirit of the pioneer and in so doing captures the fascination of the reader. Pithole, Salt Creek, Coalinga and Spindletop live again in these pages, along with Salem, West Edmond, Heidelberg and Elk Basin.

The treatment, in general, is chronological with an occasional digression of a philosophical nature which the reader will enjoy although he may not necessarily accept. Colorful anecdotes, which could be true only in an industry as lusty as oil, are sprinkled through the book. This work is recommended to everyone connected with any phase of the development of oil reserves.

Geologists, especially young geologists, will find much in this book that is valuable. The perseverance of Frank R. Clark that led to the discovery of the Yates field, the reasoning of Levorsen that resulted in the Fitts pool, the curiosity of Charles T. Lupton that uncovered the Cat Creek field are only a few of the examples of the use of "the Geological Attack." Two chapters, "Doodlebugs and Rockhounds" and "Fields That Couldn't Be There" will be especially helpful to geologists, and most of the actors in this part of the drama are men of our profession.

And why do men follow the precarious occupation of wildcatting? The author answers this question with a quotation from Robert W. Service: "It isn't the gold I'm wanting so much as just finding the gold."

[1] Darby and Bothwell, Inc., 612 Orpheum Building. Review received, June 8, 1946.

MARINE MICROBIOLOGY, BY CLAUDE E. ZoBELL

REVIEW BY ROBERT W. STONE[1]
State College, Pennsylvania

Marine Microbiology. A Monograph on Hydrobacteriology. By Claude E. ZoBell. 240 pp., 12 figs., 40 tables. Published by Chronica Botanica Company, Waltham, Massa-

[1] Associate professor of bacteriology, Pennsylvania State College. Review received, June 13, 1946.

chusetts (1946); G. E. Stechert and Company, New York City. Cloth. 7×10.5 inches. Price, $5.00.

Marine Microbiology, by Claude E. ZoBell, is a successful attempt to bring together the scattered knowledge of the activities of marine bacteria. To those who believe that the sea, which covers nearly three-fourths of the earth's surface, must hold the key to many important secrets of biology, biochemistry, and geology, it may come as no surprise that Dr. ZoBell can say "the field of hydrobiology and marine microbiology is most promising, being almost virgin, for research in pure and applied science."

To the scientist, ZoBell brings a summary of all the important work on marine microbiology to date. Although not written as a popular treatise, the book is clear and readable and is supplied with enough explanatory material that the uninitiated is not helpless among unfamiliar biological terms. The chapters are well organized so that the book is useable for either reference or background reading. The chapters on Collection of Samples, Distribution of Bacteria at Sea, Sanitary Aspects of Marine Microbiology and Microorganisms in Marine Air should be of popular interest to most readers. Of particular interest to the geologist and chemist are the chapters on Marine Environment and Activities of Microorganisms in Bottom Deposits. More detailed chemical treatment is given in chapters on the carbon, nitrogen, sulphur and phosphorus cycles. In discussing the chemical changes produced by bacteria, the author is handicapped by the scarcity of reliable experimental data, and may be forgiven for an occasional tendency to state perhaps too positively conclusions based on somewhat sketchy facts. But in view of the present state of development of marine microbiology there is room for very little but praise for the work as a whole.

Dr. ZoBell is well qualified for the task of writing this book, having spent most of his active career in research on various phases of water bacteriology and for the past several years has been associate professor of marine microbiology at the Scripps Institution of Oceanography. In addition to his broad interest in hydrobiology, the author is noted for his investigations of the part bacteria play in formation and destruction of petroleum. His book should be distinctly helpful to all fundamental research associated with marine biology.

RECENT PUBLICATIONS

ALASKA

*"Note on the Geology of Agattu, an Aleutian Island," by Robert P. Sharp. *Jour. Geol.*, Vol. 54, No. 3 (Chicago, May, 1946), pp. 193–99; 4 figs.

APPALACHIANS

"The Distribution of Several Types of Berea Sand in West Virginia, Eastern Ohio, and Western Pennsylvania," by Gordon Rittenhouse. *U. S. Geol. Survey Prelim. Map 58*, Oil and Gas Investig. Ser. (July, 1946). Map, 26×36 inches. May be purchased from Director, Geological Survey, Washington 25, D. C. Price, $0.20.

ALBERTA

*"Age of the Canadian Kootenay Formation," by W. A. Bell. *Amer. Jour. Sci.*, Vol. 244, No. 7 (New Haven, Connecticut, July, 1946), pp. 513–26; 1 chart.

ARGENTINA

*"Los Estratos de Paganzo y sus Nivelles Plantiferos en la Sierra de Los Llanos, Provincia de la Rioja" (The Estratos de Paganzo and Their Plant-Bearing Levels in the

Sierra de Los Llanos, Rioja Province), by Osvaldo Bracaccini. *Revista Soc. Geol. Argentina* Tomo 1, No. 1 (Buenos Aires, 1946), pp. 19–61; 19 figs. Summary in English, p. 60. "This paper, part of a general work on the geology of Sierra de Los Llanos, discusses briefly the composition and structure of the Estratos de Paganzo as well as the stratigraphic position of the plant-bearing levels of the Sierra, particularly those of Arroyo del Totoral where Bodenbender for the first time in South America discovered a *Glossopteris* fauna. The author is inclined to consider the redbeds of the Estratos de Paganzo as Upper Carboniferous or Lower Permian.

*"Relaciones Estratigráficas de la Region del Rio Chubut" (Stratigraphic Relations in the Region of the Rio Chubut), by Alejandro Piatnitsky. *Bol. Inform. Petroleras*, Vol. 23, No. 259 (Y. P. F., Buenos Aires, March, 1946), pp. 173–85; 10 profiles, 3 photographs, 1 map, 1 correlation chart.

COLOMBIA

*"Colombia Wildcatting," by George O. Ives. *Oil Weekly*, Vol. 122, No. 5 (Houston, July 1, 1946), International Section, pp. 3–5; 1 map, 2 photographs.

ECUADOR

*"Ecuador," *Oil Weekly*, Vol. 122, No. 5 (Houston, July 1, 1946), International Section, pp. 6–7; 5 aerial photographs.

GENERAL

*"On the Origin of Continents and Ocean Floors," by J. H. F. Umbgrove. *Jour. Geol.*, Vol. 54, No. 3 (Chicago, May, 1946), pp. 169–78; 4 figs.

*"The American Oil Man and Foreign Oil," by E. DeGolyer. *Oil Weekly*, Vol. 122, No. 5 (Houston, July 1, 1946), International Section, pp. 32–36.

*"Exploring the Continental Shelf," by Charles J. Deegan. *Oil and Gas Jour.*, Vol. 45, No. 6 (Tulsa, June 15, 1946), pp. 98–101; illus.

"The Airborne Magnetometer," by James R. Balsley, Jr. *U. S. Geol. Survey Geophysical Investigations Preliminary Report 3* (July, 1946). May be obtained, *gratis*, from Director, Geological Survey, Washington 25, D. C.

GUATEMALA

*"Guatemala Oil Possibilities," by M. M. Adams. *Oil Weekly*, Vol. 122, No. 5 (Houston, July 1, 1946), International Section, pp. 8–10; 1 map.

IRAN

*"An Appraisal of Iranian Oil," by Lester S. Thompson. *Oil and Gas Jour.*, Vol. 45, No. 8 (Tulsa, June 29, 1946), pp. 64–68; 9 illus.

OKLAHOMA

*"The Anadarko Basin—Will It Pay Off?" by Charles N. Gould. *Oil Weekly*, Vol. 122, No. 6 (Houston, Texas, July 8, 1946), pp. 60–61; 1 map.

POLAND

*"Poland's Oil Problems and Plans." *Oil Weekly*, Vol. 122, No. 5 (Houston, July 1, 1946), International Section, pp. 25–29, 36; 2 figs., 4 tables.

SOUTH AMERICA

*"Marine Early Permian of the Central Andes and Its Fusuline Faunas. Part II," by

Carl O. Dunbar and Norman D. Newell. *Amer. Jour. Sci.*, Vol. 244, No. 7 (New Haven, Connecticut, July, 1946), pp. 457–91; 12 pls.

WYOMING

"Geology of the Bargee Area, Fremont County, Wyoming," by M. Dean Williams and H. H. R. Sharkey. *U. S. Geol. Survey Prelim. Map 56*, Oil and Gas Investig. Ser. (June, 1946). Single sheet, 24×32 inches. Maps, cross sections, and text. For sale by Director, Geological Survey, Washington 25, D. C.; Federal Building, Casper, Wyoming; Boston Building, Denver, Colorado; Federal Building, Tulsa, Oklahoma. Price, $0.40.

ASSOCIATION DIVISION OF PALEONTOLOGY

**Journal of Paleontology* (Tulsa, Oklahoma), Vol. 20, No. 4 (July, 1946).

"Weches Eocene Ostracoda from Smithville, Texas," by Morton B. Stephenson.

"Glyptobairdia, a New Genus of Ostracoda," by Morton B. Stephenson.

"Foraminifera of the Coos Bay Lower Tertiary, Coos County, Oregon," by Mildred Riechers Detling.

"Ostracoda from the Upper Jurassic Cotton Valley Group of Louisiana and Arkansas," by Frank M. Swartz and Frederick M. Swain.

"Ostracoda from the Tertiary of Florida," by Frederick M. Swain.

"Allegheny Fossil Invertebrates from Eastern Ohio," by A. K. Miller and Myron T. Sturgeon.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
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THE ASSOCIATION ROUND TABLE

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REPRESENTATIVE ON DIVISION OF GEOLOGY AND GEOGRAPHY NATIONAL RESEARCH COUNCIL: PHILIP B. KING (1949)

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FALL MEETING, BILOXI, MISSISSIPPI
OCTOBER 24, 25, 26, 1946

The executive committee has accepted the invitation of the Mississippi Geological Society to sponsor a fall meeting at Biloxi, Mississippi, on October 24, 25, and 26. The Buena Vista Hotel at Biloxi is to be headquarters and other hotels at Biloxi and at Gulfport (6½ miles away) will assist. All requests for hotel accommodations should be made with the Buena Vista Hotel, Biloxi. Members are requested to "double-up" where possible (two in one twin-bed room).

The technical program is planned to present the general geologic features of the southeastern states, covering stratigraphy from early Paleozoic to Recent, tectonics and structure of the region, the Mississippi salt basin, and detailed papers on outstanding fields.

Frederic F. Mellen, president of the Mississippi Geological Society, at Jackson, announces the appointment of J. B. Storey, immediate past-president of the Society, as chairman of arrangements. Further announcements will be made.

There will be a registration fee of $2.50.

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MEMORIAL

HAROLD KURTZ SHEARER
(1889–1946)

Harold Kurtz Shearer was born January 31, 1889, in Springfield, Ohio, and died in the city of Salvador, Bahia, Brazil, on January 17, 1946, after having suffered a cerebral hemorrhage two days previously. He is survived by his wife, Louise Woods Shearer, and

HAROLD KURTZ SHEARER

his son, Harry W. Shearer. He is also survived by his father, Harry K. Shearer, a brother, Karl K. Shearer, and a sister, Mrs. Lucille Printz, all of Springfield.

After having received his primary and secondary school education in Springfield, he

entered Wittenberg College in Ohio where he majored in geology and chemistry. In the fall of 1910 he transferred to the University of Chicago where he graduated in 1911 with the degree of Bachelor of Science, having continued his major courses of geology and chemistry.

Leaving Chicago, he joined a party of geologists directed by C. K. Leith of the University of Wisconsin and went to Brazil where he acted as chemist and geologist on a field survey of the famous iron ore deposits near Itabira, Minas Gerais, for the Brazilian Iron and Steel Company. During these two years in Brazil, Hal acquired a taste for foreign work and became proficient in the Portuguese language, both of which were to play important parts in his later life.

Leaving Brazil in mid-1913 he entered the University of Wisconsin where he graduated with the degree of Master of Science in geology in 1914. He joined the Alpha Tau Omega Fraternity of Wittenberg College and became a Sigma Xi at the University of Chicago. He was an industrious and brilliant student throughout his rather broad college experiences.

After receiving the Master's degree from Wisconsin he joined the staff of the Geological Survey of Georgia as assistant State geologist, succeeding Oliver B. Hopkins, now of the Imperial Oil Company of Toronto. J. E. Brantly, who had succeeded S. L. Galpin, now of the University of West Virginia, several months before, was likewise assistant State geologist at the time Harold Shearer joined the Survey. These two were associated together and though working on different subjects frequently worked together in the same areas. Shearer's work on the Georgia Survey included field studies of, and excellent and exhaustive reports on, bauxite and fullers earth. *Bulletin 31*, "Bauxite and Fullers Earth of the Coastal Plain of Georgia," was published in 1917. This was followed by a study and a report on a part of the pyrite deposits of Georgia, which was published as *Bulletin 33* in 1918, with J. P. D. Hull, the present business manager of the Association, as co-author. He also wrote a report on the slate deposits of Georgia, published as *Bulletin 34* in 1918, in which he first described the high-potash shales or semi-slates of the Cartersville formation of Lower Cambrian age in northwestern Georgia. In 1919, in *Professional Paper 120-C* of the United States Geological Survey, C. Wythe Cooke and Harold K. Shearer published a discussion of the deposits of Claiborne and Jackson age of Georgia.

Thus, during a period of about four years on the Georgia Survey, he studied and reported on bauxite, fullers earth, pyrite, slate, and the stratigraphy of certain deposits of Tertiary age of the Coastal Plain. Such a variety of subjects in such a brief length of time was by no means beyond his mental capacity and in each he did very fine field work which he was easily capable of describing and discussing because of his proficiency as a writer.

Leaving the Georgia Survey, he volunteered for the Army and joined the Officer's Training School at Camp Taylor, Kentucky. The war ended prior to his graduation from the Field Artillery School. Returning home after being discharged, he visited his family for a few months for the first time in many years and then upon receipt of a telegram from J. E. Brantly he came to Texas to enter the oil industry. His first job was firing a battery of drilling boilers on a contractor's rig operating in the northwest extension of the old Burkburnett field. After a month or two in the field he came to Dallas and accepted a partnership with H. S. Scott as a consulting geologist. This was in the spring of 1919. He later became associated with the old Invincible Oil Corporation and the Louisiana Oil Refining Corporation at Shreveport. In June, 1920, he went to Mexico on a consulting job in association with Edwin B. Hopkins. He and Brantly sailed together from New Orleans to Tampico. After several years of work in and out of Mexico and Central America he returned to Shreveport and joined the staff of Standard Oil Company of Louisiana,

with which company he remained until 1931 when he joined The Hunter Company, Inc., remaining with it until 1942.

During the period of his work in Louisiana, Arkansas, Mississippi, and East Texas, Shearer published a number of papers on geology and oil and gas development in those several areas. These were published by the A.A.P.G. and the A.I.M.E.

In 1943 Shearer returned to Brazil, after an absence of 30 years, as a senior geologist with the Board of Economic Warfare. During this period he spent most of his time on quartz and made one very tedious and exhaustive trip up the Rio Tocantines into the heart of the northern part of the Brazilian Plateau. The results of his studies in Brazil were published by the Geological Department of the Government of Brazil and constituted one of the outstanding works and publications of the many American geologists who were in the country studying mineral deposits for the benefit of the governments of the United States of America and of the United States of Brazil in their conduct of the war.

In the spring of 1944 Shearer and Brantly met again in Brazil and in the fall of that year Shearer joined Brantly's organization, Drilling and Exploration Company, Inc., as chief geologist in Brazil. Thus, these two men commenced work together as young geologists on the Georgia Survey and they were together again after 30 years, when it ended for one.

Harold Shearer was a man with a brilliant mind which he was capable of applying with all the industry that is required for fine accomplishment. He was an excellent student of geology and he was a splendid and precise writer. He was thorough and endlessly painstaking on detail and yet his mind was fully capable of viewing a problem in its broadest aspects. He was truly a scientist and in the science of geology he accomplished much, but could have accomplished much more had his environment been more suitable to his abilities and more congenial to a man of his type. Harold Shearer was a man of fine sensibilities, the highest integrity, with a gentle, if not timid, nature. These traits of character rendered the chosen field of his profession, the oil industry, a difficult one for him. He had one of the finest geological minds that I ever had the privilege of knowing, and I make no exceptions. In broader aspect, Shearer's life and science touched on all phases of geology and carried him through many countries from Canada to Brazil. Wherever he passed he knew and recognized the history of the things which he saw, or he stopped to learn them.

J. E. BRANTLY

DALLAS, TEXAS
June 21, 1946

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 30, NO. 8 (AUGUST, 1946), PP. 1318-1320

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

The retirement of FRANK W. DEWOLF as professor of geology and head of the department of geology and geography at the University of Illinois becomes effective September 1, 1946. He has helped to educate many petroleum geologists during the past 15 years, and has encouraged many to join the Association. He himself became a member in 1920, was vice-president in 1923, and "runner-up" for the presidency in 1929. Frank graduated at Chicago in 1903, entered the United States Geological Survey the next year, and worked first as assistant to FREDERICK G. CLAPP in the survey of oil and coal lands in southwestern Pennsylvania. In 1906 he was detailed to work in Illinois in cooperation with the State Survey. Later he was head of the Survey from 1910 until March, 1923. when he became chief geologist of the Humphreys Oil Company in Dallas, in association with F. JULIUS FOHS, vice-president. He was in charge of an active geological and land department that participated in the development of many fields, including Powell, Richland, Wortham, and Nacona in Texas, and a considerable number in Oklahoma. After the company moved headquarters to Houston, DeWolf actively directed geophysical and geological work and wildcat drilling in the Gulf Coast and in West and North Texas.

In 1928 he was placed in charge of operations of the Louisiana Land and Exploration Company in association with E. DEGOLYER, then of the Amerada. This resulted in seismograph operations covering nearly three million acres of coastal land, and the discovery of nine salt domes in a like number of months; this record probably has not been equalled. These and other properties of the company were subsequently developed by The Texas Company under an operating contract. Such an experience in the oil fields and in the management of the Illinois State Survey gave DeWolf an unusually favorable background from which to draw in the development of professional geologists at the University of Illinois. His successor has not yet been designated.

R. A. SMITH, Michigan State geologist, who has been in the State Geological Survey for 35 years, was honored at a dinner held at the Mt. Pleasant Country club, Friday, June 28. He plans to retire from the office this summer. The dinner was a joint meeting of the Michigan Geological Society and the Michigan chapter of the American Petroleum Institute.

About one half of the area of the United States is favorable for gas production, HUGH D. MISER, chief of the United States Geological Survey's Fuels Section, told the Federal Power Commission recently. He stated that "as long as the intensified search for oil continues, there will be additions to the natural gas reserve" and that the "discovery rate of natural gas is increasing." He estimated proved natural gas reserves at 140 trillion cubic feet.

FAWZI ISKANDER, the Egyptian geologist of the Standard Oil Company of Egypt, has been in the United States since March, receiving a training course in geophysical exploration methods with the Carter Oil Company. He will return to his country by the end of the year.

ALFRED R. LOEBLICH, JR., is now associate curator of invertebrate paleontology at the United States National Museum, Washington 25, D. C.

E. GAIL CARPENTER, consulting geologist of Wichita, Kansas, is running for Lieutenant Governor in Kansas on the Republican ticket.

P. B. NICHOLS of Oklahoma City has resigned his position as district geologist for the Cities Service Oil Company as of July 1 to be president of The Geolograph Company with offices at 25 North Western, Oklahoma City. Nichols is the inventor of the Geolograph mechanical well-logging instrument.

RICHARD M. FOOSE, senior geologist of the Pennsylvania Geological Survey, will resign from his position September 1, 1946, to accept the post of professor of geology and head of the department of geology at Franklin and Marshall College, Lancaster, Pennsylvania. In addition to his duties in organizing a new department of geology at Franklin and Marshall College, Foose will continue to serve as a consulting geologist.

VIRGIL G. FEATHER, formerly with the Anchor Exploration Company, is now with the Honolulu Oil Corporation, at Lubbock, Texas.

CHARLES E. DECKER, research professor of paleontology, Norman, Oklahoma, has been active in field work this summer in Virginia and Tennessee. In a trip of three weeks, H. B. BURWELL, State geologist of Tennessee, and ARTHUR BEVAN, State geologist of Virginia, furnished him transportation and a man to assist in collecting graptolites primarily from the Athens shale, but an additional exceptionally fine collection of Cambrian branching graptolites was secured near Knoxville, Tennessee, and two large cartons of graptolites were shipped from that state. In Virginia, BYRON COOPER, head of the department of geology at Virginia Polytechnic Institute at Blacksburg, assisted in collecting from many localities, so that six nail kegs filled with graptolites were shipped from Virginia, all of these to become part of the permanent collections of the University of Oklahoma.

VINCENT EVANS has resigned as geologist for the Carter Oil Company in eastern Colorado and is now in the employ of the Skelly Oil Company, as geologist, in the same region. He is situated at La Junta, Colorado.

WILLIAM R. GRAY has resigned from Geophysical Service, Inc., and has joined the Sun Oil Company, Dallas, Texas, as research geologist in the Dallas micro-paleontology laboratory.

E. G. DAHLGREN, assistant secretary of the Interstate Oil Compact Commission, Oklahoma City, Oklahoma, has begun a compilation of secondary recovery projects throughout the Nation in obtaining material for a chapter entitled "Magnitude of Secondary Recovery Operations" which will be published in the new American Petroleum Institute book on "The Development and Operation of Secondary Recovery Projects" which is scheduled for publication in the early part of 1947. Material will be obtained from the various Compact committees and other sources.

SHERMAN A. WENGERD, in the exploration department of the Shell Oil Company, Inc., at Wichita Falls, Texas, has been elected to chapter membership in the Harvard Chapter of Sigma Xi—the society for promotion of research in science.

OTTO E. BROWN is with the Gulf Oil Corporation at Sheridan, Wyoming.

R. J. DILGER is employed as general manager for Fred M. Manning, Inc., drilling contractor of Denver, Colorado. Dilger's address is Hamilton Building, Wichita Falls, Texas.

E. J. HANDLEY, recently with the Shell Oil Company, Inc., is with the Continental Geophysical Service, Tulsa, Oklahoma.

H. BAGGELAAR, recently at Maracaibo with the Caribbean Petroleum Company, may be addressed in care of J. Baggelaar, van Blankenburgstraat 80, Den Haag, Holland.

Captain R. V. BROWNE, who has been in India, may be addressed at 192 Hagley Road, Hayley Green, Halesowen, Worcs., England.

WILLIAM M. CARTMELL and RALPH C. BREHM, of the firm of Brehm and Cartmell, consulting petroleum geologists, have opened an office at 528 Clayton Building, Sapulpa, Oklahoma.

D. T. RING, of Columbus, Ohio, was elected president of the Pennsylvania Grade Crude Oil Association, at the 22d annual meeting, held at Pittsburgh. Ring is vice-president in charge of oil production for the Preston Oil Company of Ohio, the Union Gasoline and Oil Corporation of Pennsylvania and West Virginia, and the Virginian Gasoline and Oil Company of Kentucky and West Virginia.

CLINTON ENGSTRAND and J. D. DAVIES are conducting the Kansas Sample Log Service at 415 North Pershing, Wichita, Kansas.

R. B. TRAVIS returned to civilian rank on March 14 and is now employed by the Standard Oil Company of California, producing department, at Bakersfield, California.

WILSON G. SAVILLE, senior partner in Gravity Meter Exploration Company, Houston, and former United States Army district engineer at Galveston, was sworn in as chairman of the Houston-Harris County Port Commission early in July after his appointment by the Houston City Council and Harris County Commissioners Court.

The World Conference on Mineral Resources and the 75th A.I.M.E. Anniversary Celebration, originally announced for September, 1946, have been postponed to the week of March 17, 1947.

The International Petroleum Show and Congress previously scheduled for May, 1947, at Tulsa, Oklahoma, have been postponed until 1948.

President EARL B. NOBLE, of Los Angeles, has returned from a month's stay in Paraguay, where the Union Oil Company of California, of which he is manager of exploration, is developing a wildcat concession.

Past-president MONROE G. CHENEY, president of the Anzac Oil Corporation, Coleman, Texas, has been in the Rocky Mountain region during June and July.

Editor GAYLE SCOTT, of Texas Christian University, Fort Worth, was at the T. C. U. summer camp at Buttrill Ranch, Marathon, Texas, for six weeks in July and August.

MARK C. MALAMPHY, recently with the United States Bureau of Mines at Little Rock, Arkansas, has gone to South Africa, where he may be addressed in care of the O'Kiep Copper Company, Nababeep, Cape Province.

RAYMOND F. BAKER, chief geologist of The Texas Company, New York, N.Y., is a director of the Witherbee Sherman Corporation, which has iron mines at Mineville, New York.

FRANK REEVES, consulting geologist of Kensington, Maryland, has returned from Germany where he reviewed recent petroleum development.

The fall meeting of the Association will be held on October 24–26 at the Buena Vista Hotel, Biloxi, Mississippi.

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Meetings will be announced. Visiting geologists and friends are welcome.

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Vice-President - - - - - - - Paul A. Harper
Cities Service Oil Company
Secretary-Treasurer - - - Francis E. Mettner
Transwestern Oil Company
605 Union National Bank Building

Regular Meetings: 7:30 P.M., Geological Room, University of Wichita, first Tuesday of each month. The Society sponsors the Kansas Well Log Bureau, 412 Union National Bank Building, and the Kansas Well Sample Bureau, 137 North Topeka.

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Humble Oil and Refining Company
Secretary-Treasurer - - - - - Philip R. Allin
Gulf Refining Company, Harvey, La.

Meets the first Monday of every month, October-May inclusive, 7:30 P.M., St. Charles Hotel. Special meetings by announcement. Visiting geologists cordially invited.

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Union Producing Company

Meets monthly, September to May, inclusive, in the State Exhibit Building, Fair Grounds. All meetings by announcement.

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Secretary - - - - - - - - - Lloyd D. Traupe
Ohio Oil Company
Treasurer - - - - - - - - - D. E. Newland
Magnolia Petroleum Company

Meetings: Dinner and business meetings third Tuesday of each month at 7:00 P.M. at the Majestic Hotel. Special meetings by announcement. Visiting geologists are welcome.

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Pure Oil Company
402 2d Natl. Bank Bldg., Saginaw
Business Manager - - - Kenneth A. Gravelle
Gulf Refining Company, Box 811, Saginaw

Meetings: Bi-monthly from November to April at Lansing. Afternoon session at 3:00, informal dinner at 6:30 followed by discussions. (Dual meetings for the duration.) Visiting geologists are welcome.

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Stanolind Oil and Gas Company
Secretary-Treasurer - - - - - - - H. L. Spyres
Skelly Oil Company

Meetings: First and third Thursdays of each month, from October to May, inclusive, at 7:30 P.M., Edwards Hotel, Jackson, Mississippi. Visiting geologists welcome to all meetings.

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The Texas Company, Box 539
Vice-President - - - - - Paul L. Bartram
Phillips Petroleum Company
Secretary-Treasurer - - - - - - - Ben S. Curtis
Independent, Box 156

Dinner meetings will be held at 7:00 P.M. on the first Wednesday of every month from October to May, inclusive, at the Ardmore Hotel.

OKLAHOMA CITY GEOLOGICAL SOCIETY
OKLAHOMA CITY, OKLAHOMA

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Carter Oil Company
Vice-President - - - - - - - Harold J. Kleen
Skelly Oil Company
Secretary-Treasurer - - - - Frederick H. Kate
Shell Oil Company, Inc.
965 First National Building

Meetings: Technical program each month, subject to call by Program Committee, Oklahoma City University, 24th Street and Blackwelder. Luncheons: Every second and fourth Thursday of each month, at 12:00 noon. Y.W.C.A.

OKLAHOMA

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Vice-President - - - - - - Henry A. Campo
Atlantic Refining Company
Secretary-Treasurer - - - - Marcelle Mousley
Atlantic Refining Company, Box 169

Meets the fourth Thursday of each month at 8:00 P.M., at the Aldridge Hotel. Visiting geologists welcome.

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Ashland Oil and Refining Company
Editor - - - - - - - - Robert F. Walters
Box 661, Gulf Oil Corporation

Meetings: First and third Mondays, each month, from October to May, inclusive at 8:00 P.M., University of Tulsa, Kendall Hall Auditorium. Luncheons: Every Friday (October-May), Chamber of Commerce Building.

TEXAS

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CORPUS CHRISTI, TEXAS

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The Texas Company, 902 Jones Building
Vice-President - - - - - - Dale L. Benson
Sinclair Prairie Oil Company, Box 480
Secretary-Treasurer - - - - O. G. McClain
Consultant, 224 Nixon Building

Regular luncheons, every Wednesday, Petroleum Room, Plaza Hotel, 12:05 P.M. Special night meetings, by announcement.

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DALLAS, TEXAS

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Magnolia Petroleum Company, Box 900
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Secretary-Treasurer - - - - John M. Clayton
Seaboard Oil Company, 1400 Continental Building
Executive Committee - - - - Fred H. Wilcox
Magnolia Petroleum Company

Meetings: Monthly luncheons by announcement. Special night meetings by announcement.

EAST TEXAS GEOLOGICAL SOCIETY
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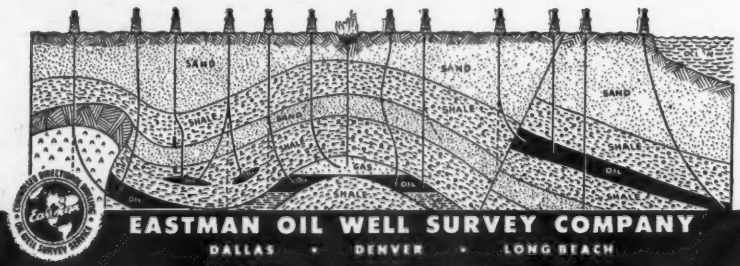

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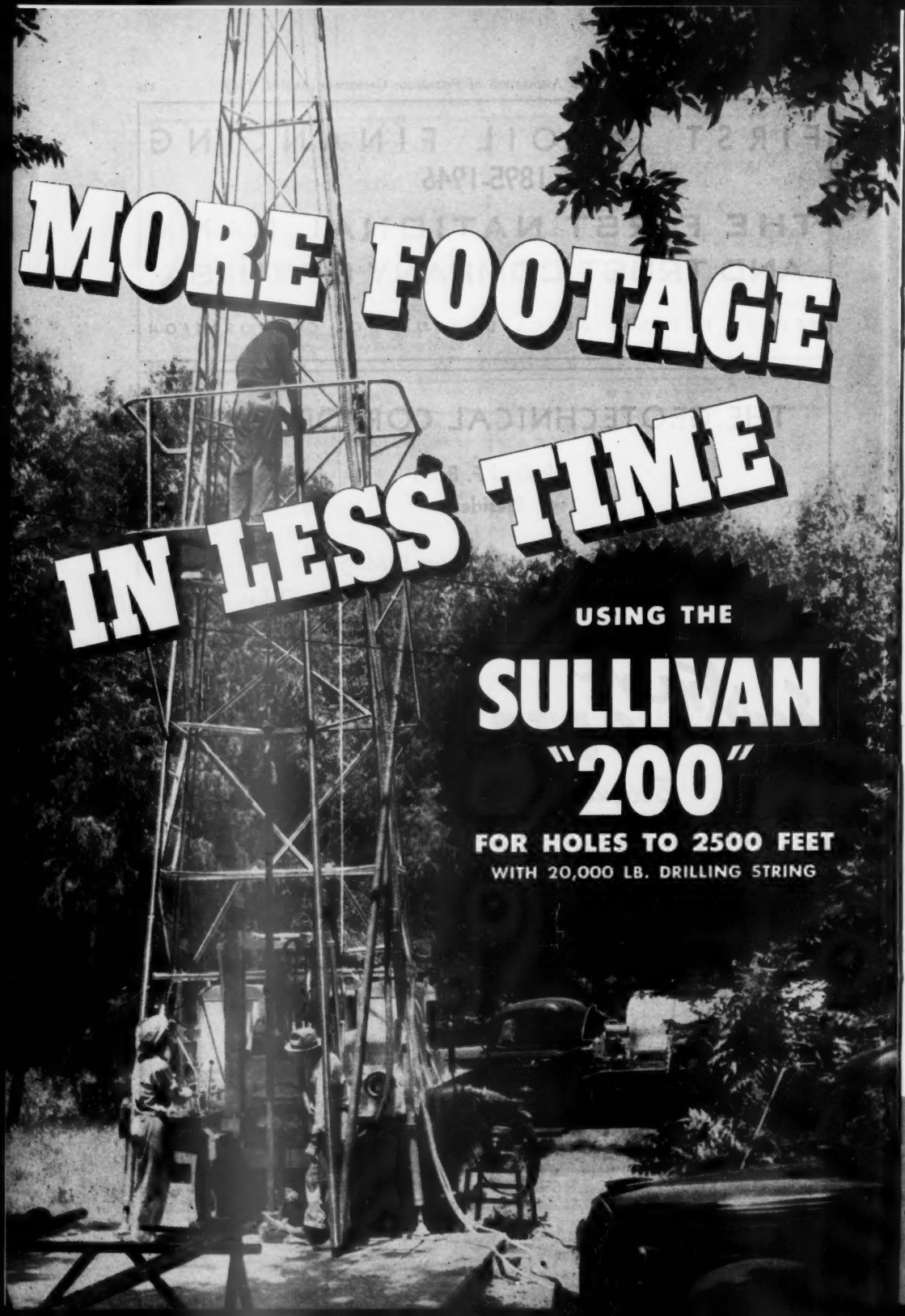
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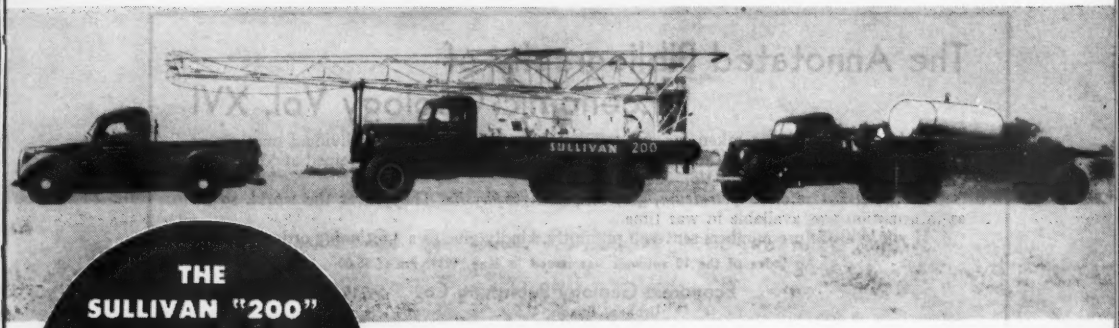

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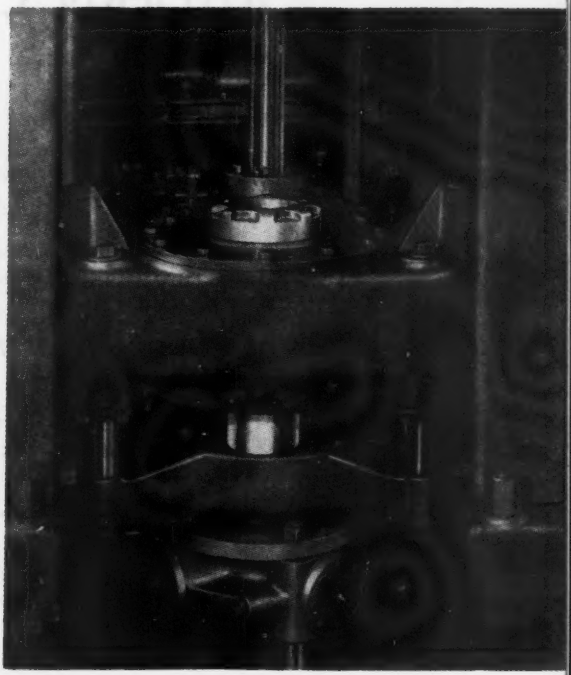

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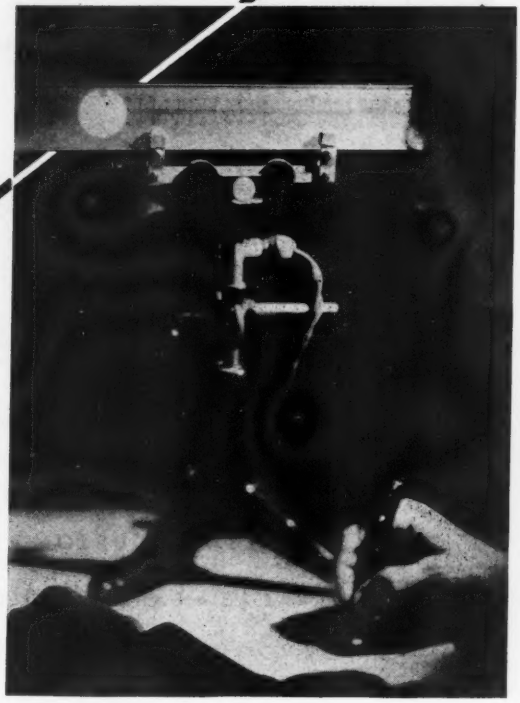

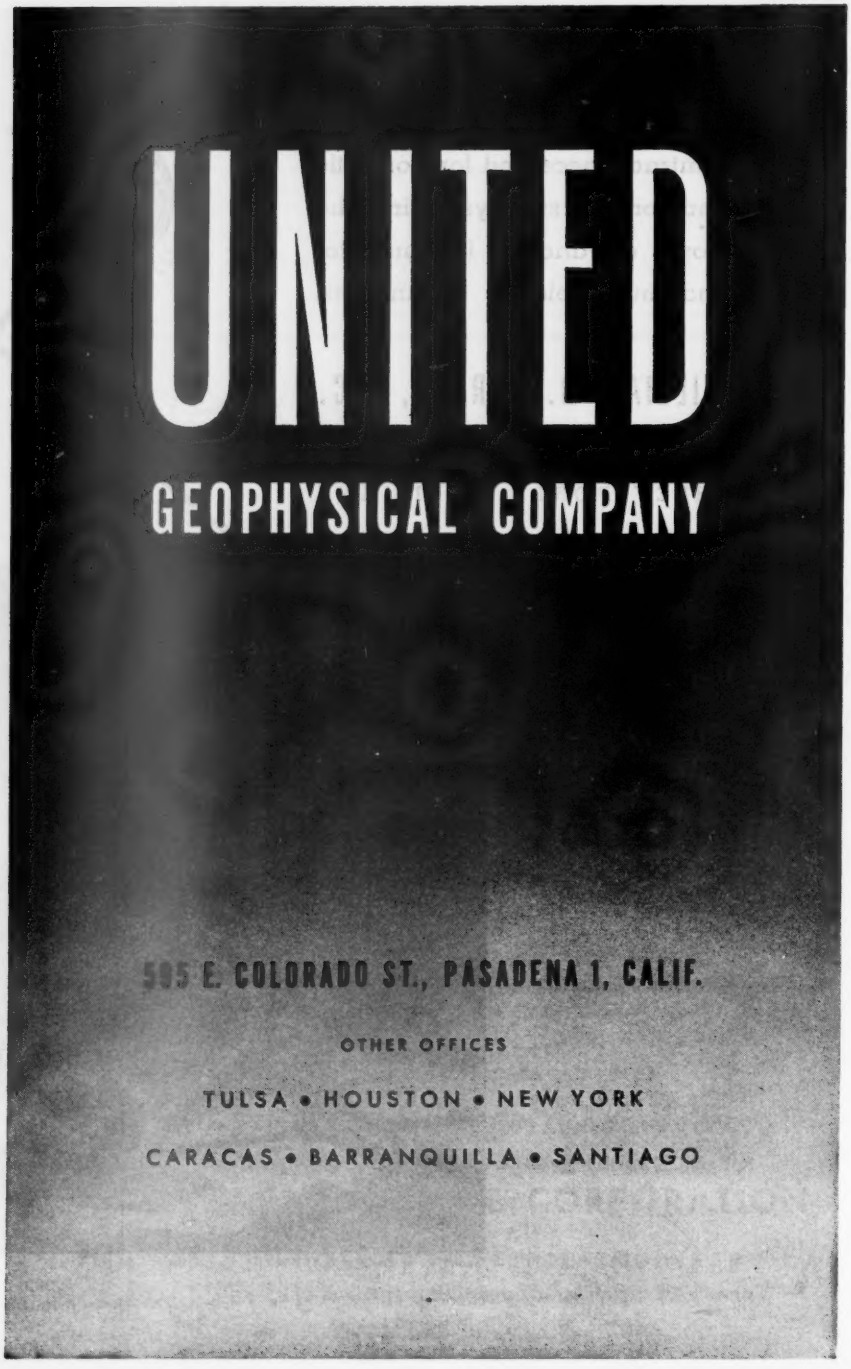
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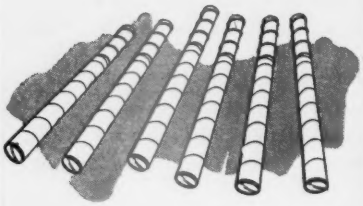

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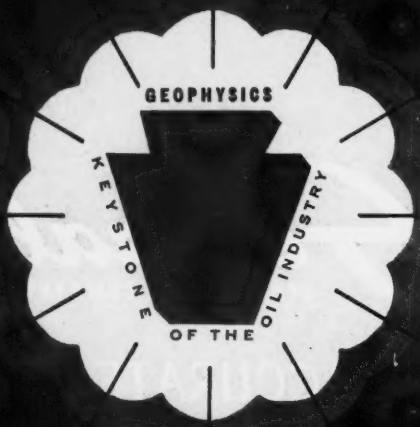

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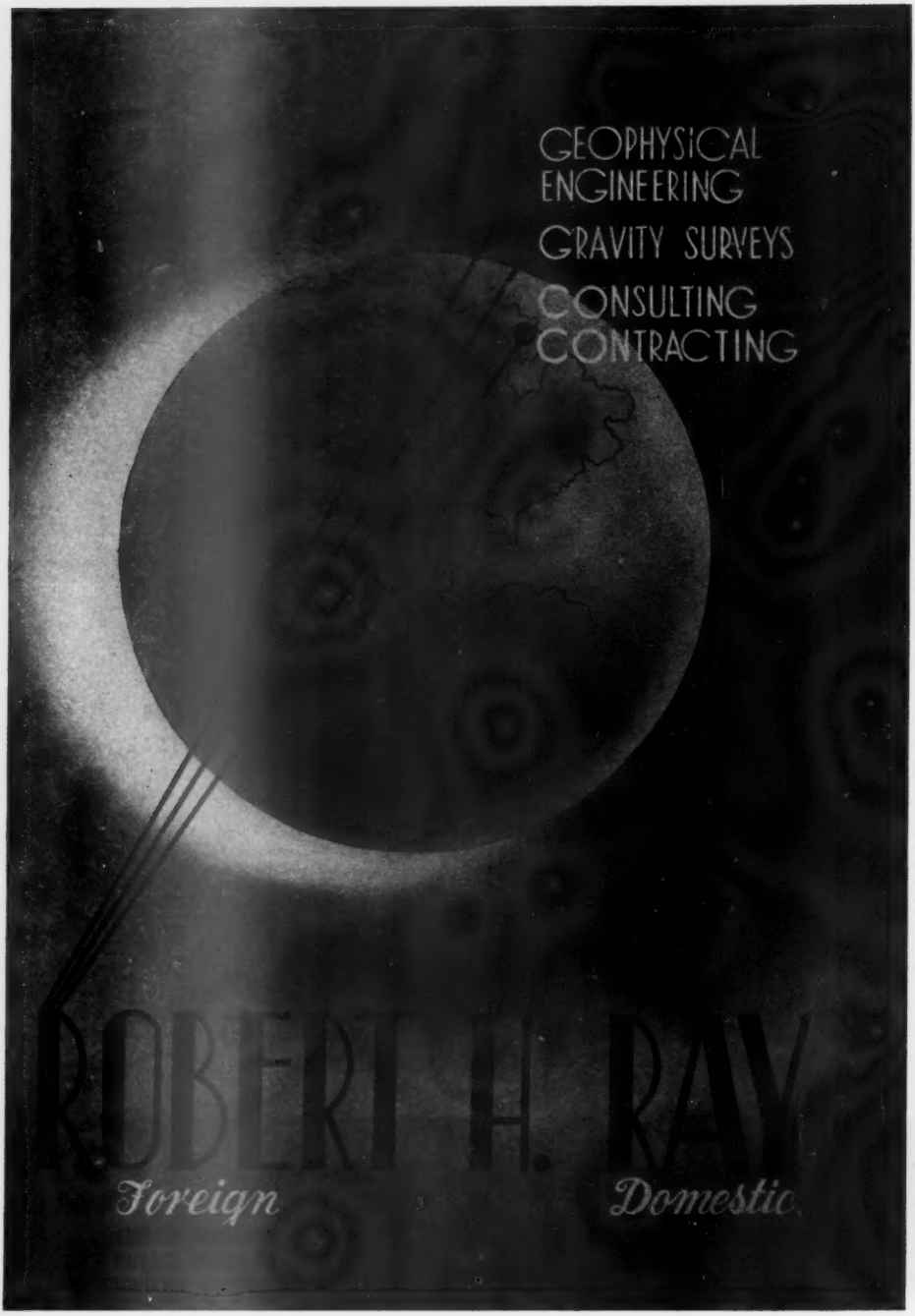
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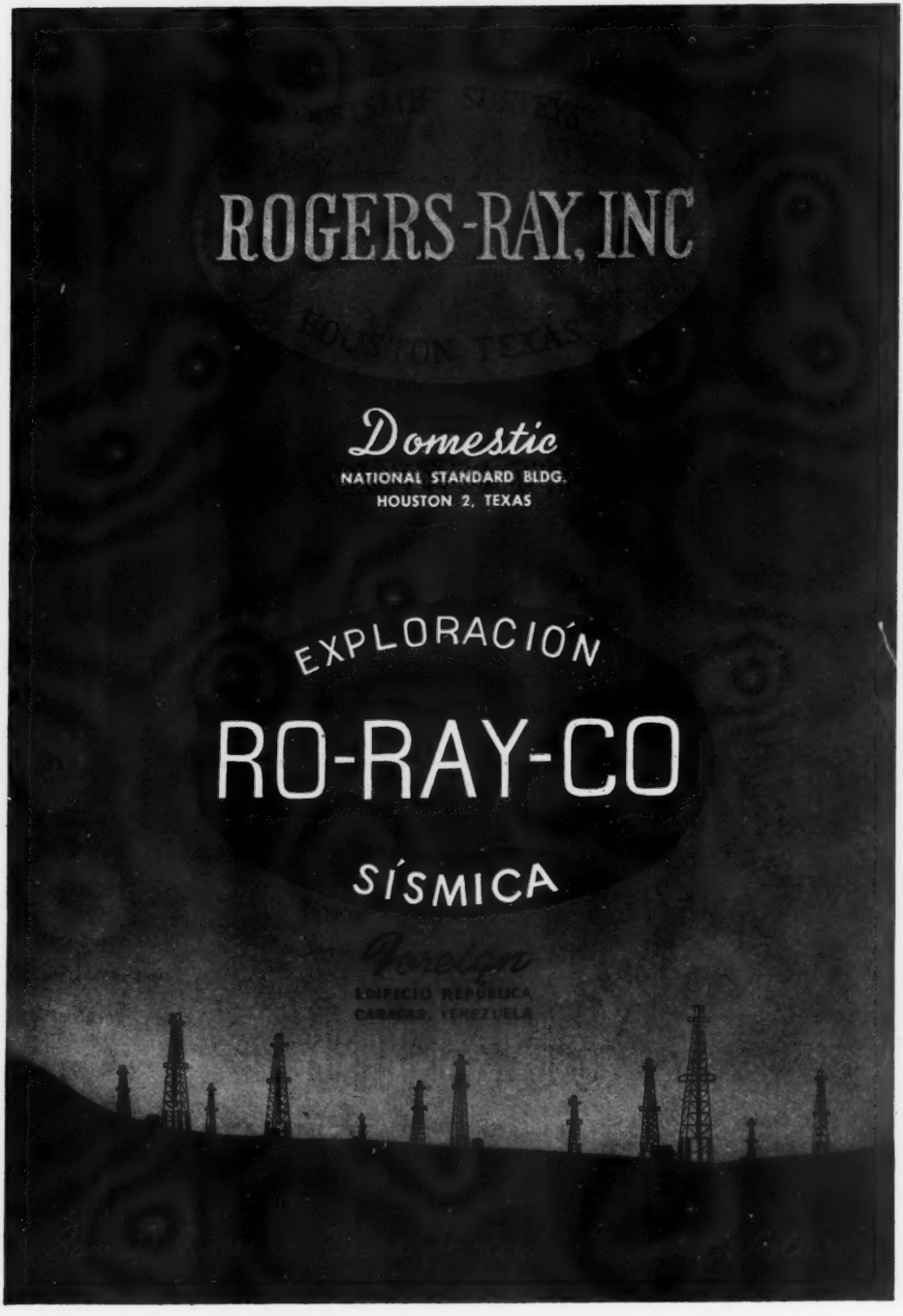
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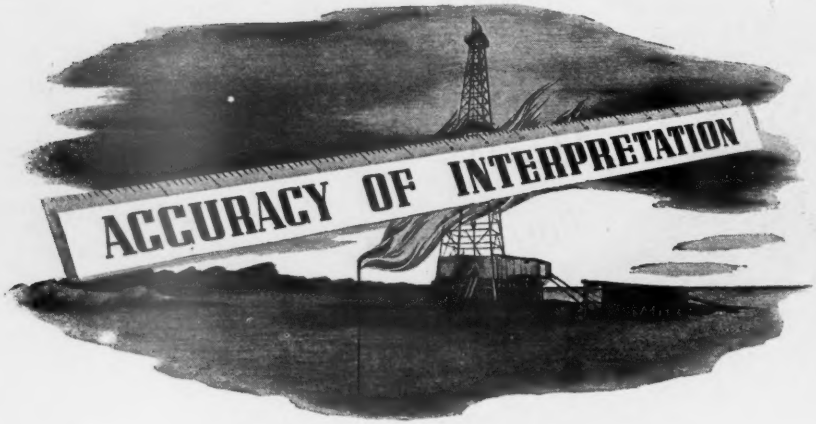

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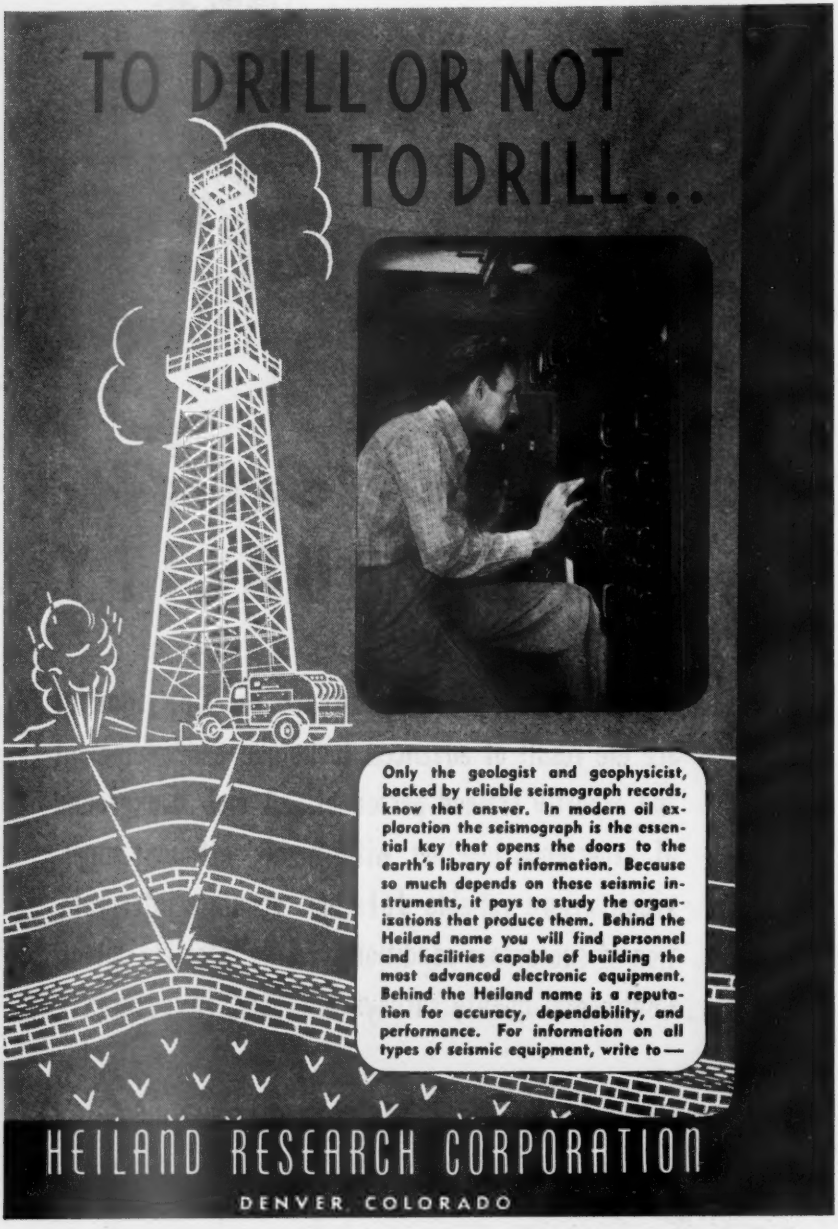
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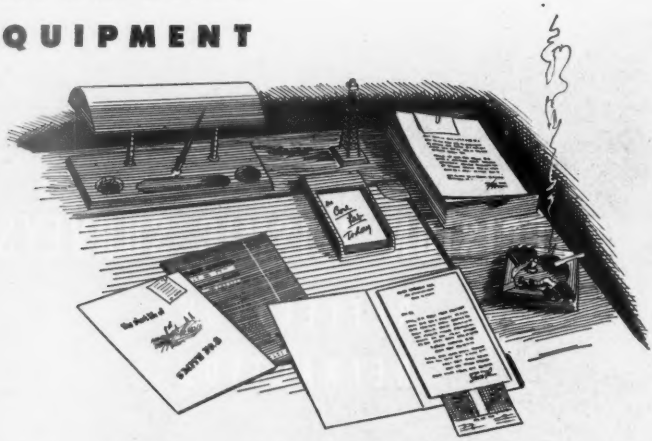

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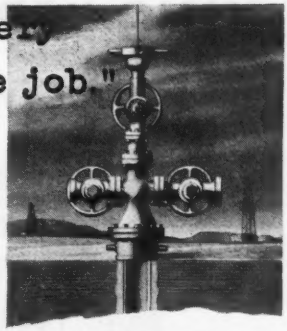

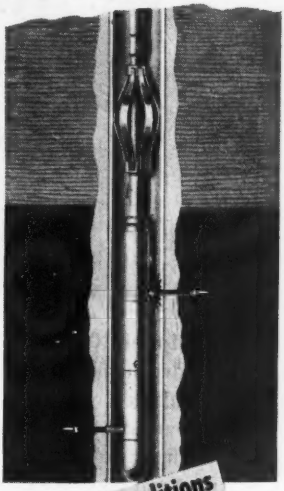

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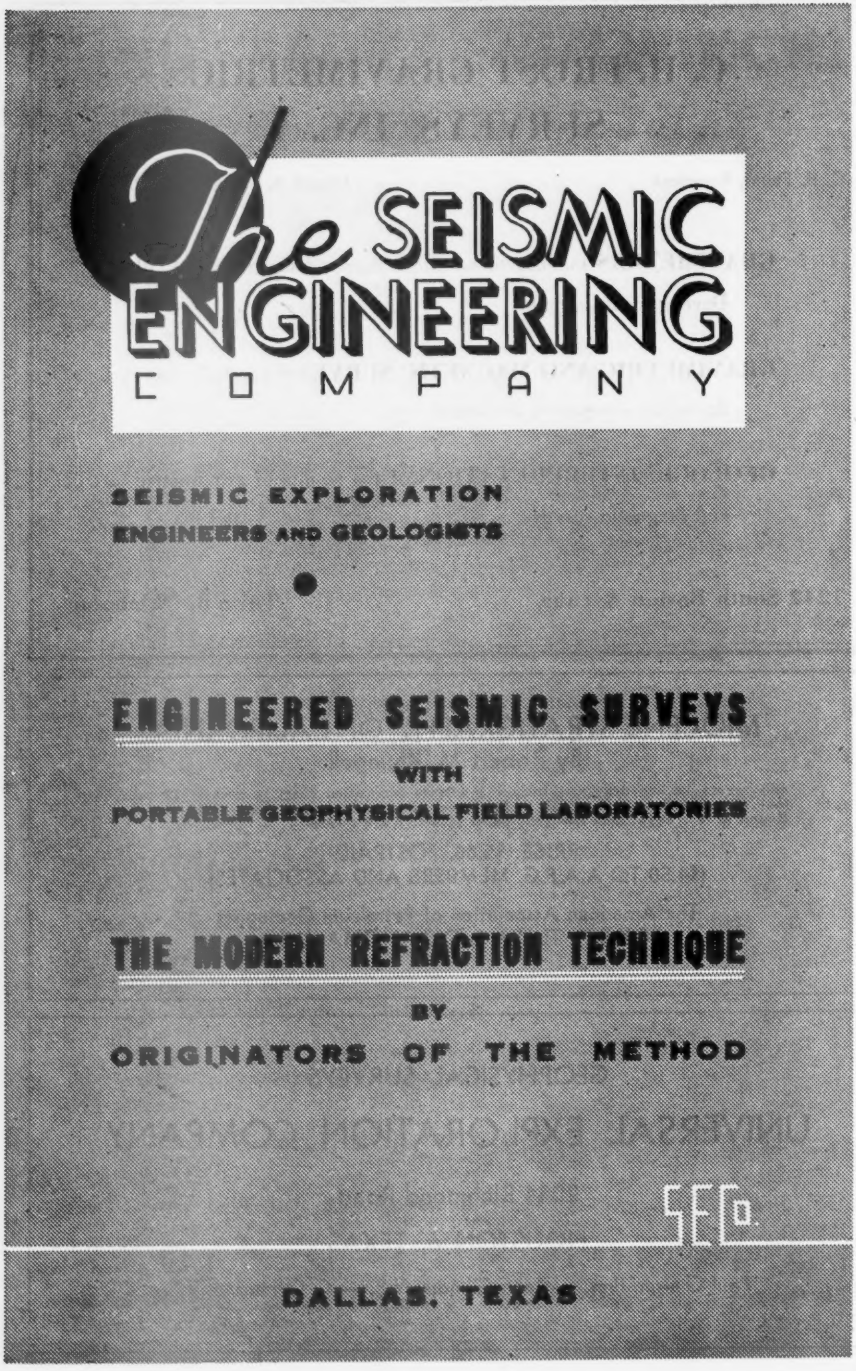
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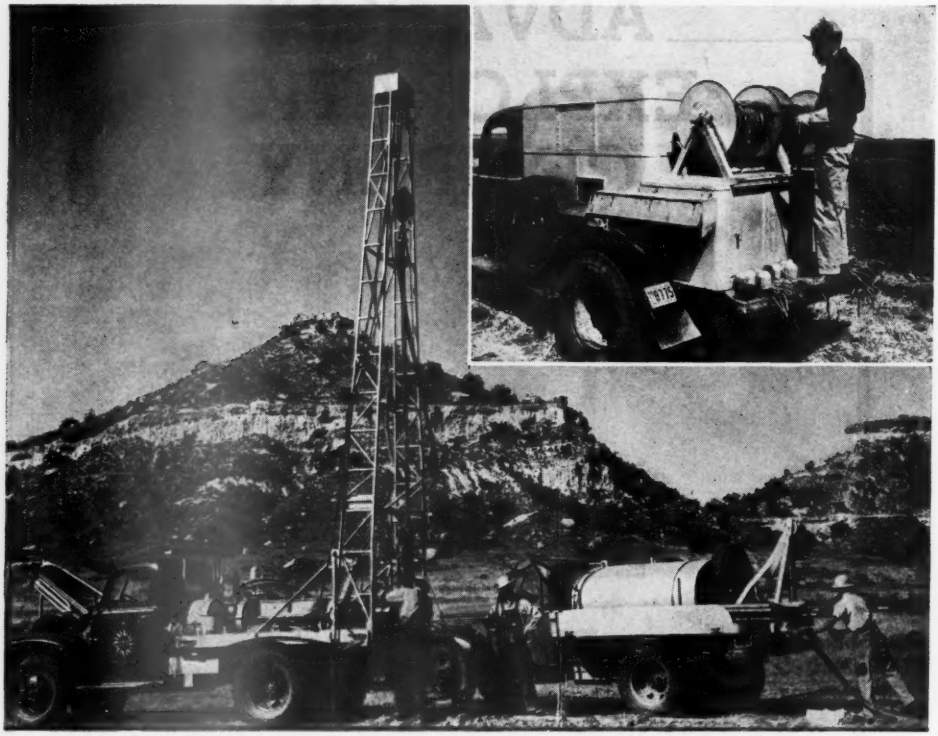

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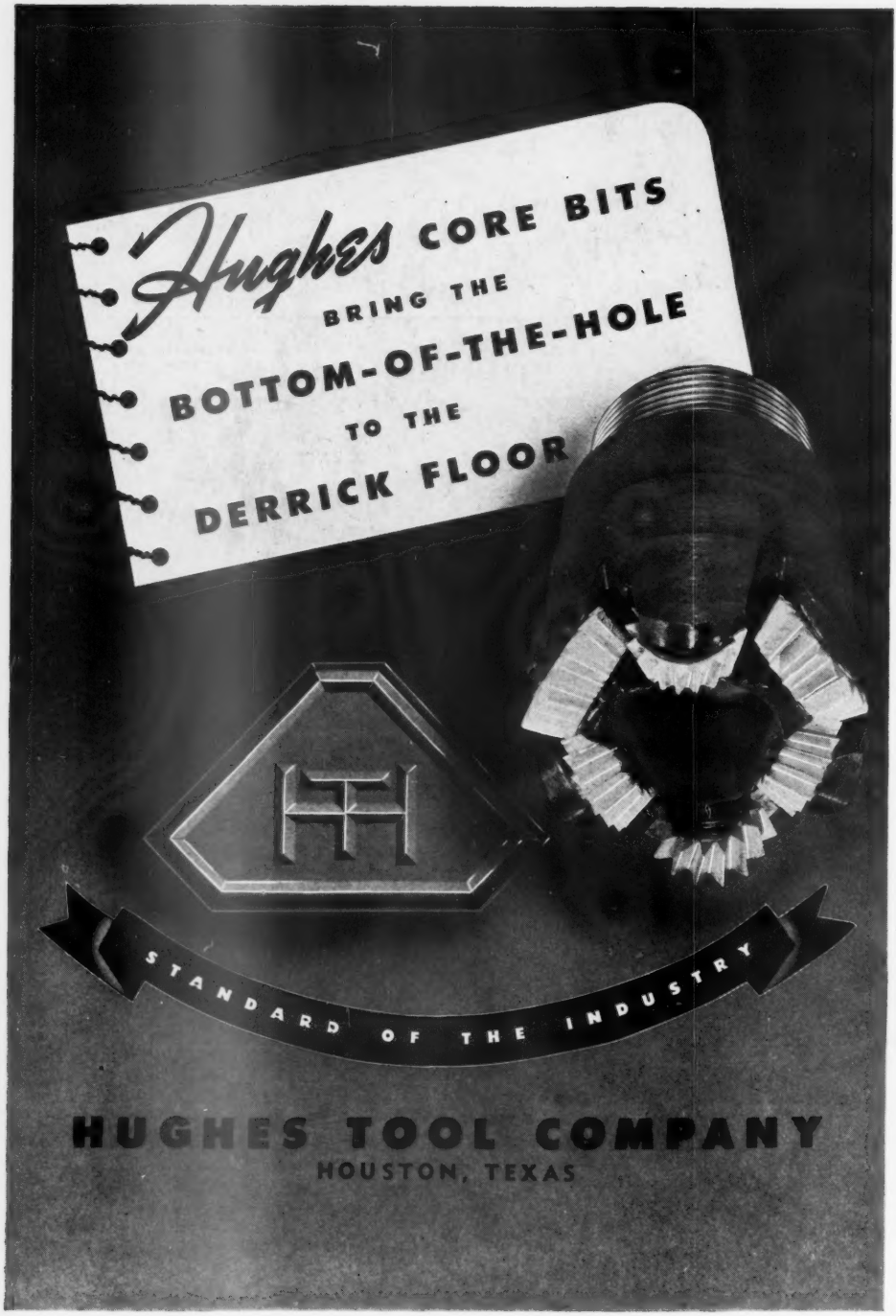

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